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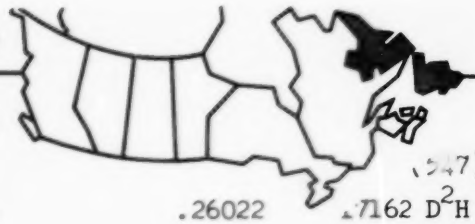
Tree Mass Equations For Common Species Of Newfoundland

M.B. Lavigne
Newfoundland Forest Research Centre

N-X-213



Energy ENFOR from the Forest

Total		if $D^2H \leq 547$	
	.547) + .018880 (D^2H - 547)	if $D^2H > 547$	
Bole	.26022 .7162 D^2H	if $D^2H \leq 547$	.9
	.26022 + .017162 (.7)	if $D^2H > 547$	
Wood	.10764 +	if $D^2H \leq 547$	.3
	.107	$D^2H > 547$	
Bark*		547	.0
		47	
Branches			.7941 .1
Fol. + tw			.6821 2.10
Total		38	10.30
Bole		83	.37
Wood		51	.15
Bark*		9633	.00
Branches			.6968 .4
Fol. + twigs*		342	.0484
		1342	
Tot	292 (123)	123)	if $D^2H \leq 123$
			if $D^2H > 123$
Bole	.10336 + .02922 D^2H	if $D^2H \leq 123$	.0 .6
	.10336 + .02922 (123) + .017495 (D^2H - 123)	if $D^2H > 123$	
Wood	.05935 + .025401 D^2H	if $D^2H \leq 123$	.0 1.26

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TREE MASS EQUATIONS FOR COMMONS SPECIES OF NEWFOUNDLAND

by M.B. Lavigne

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FOREWORD

ENFOR is the acronym for the Canadian Government's ENergy from the FORest (Energie de la FORêt) Program of research and development aimed at securing the knowledge and technical competence to facilitate in the medium to long-term a greatly increased contribution from forest biomass to our nation's primary energy production. This program is part of a much larger federal government initiative to promote the development and use of renewable energy as a means of reducing dependence on petroleum and other non-renewable energy sources.

The Canadian Forestry Service (CFS) administers the ENFOR Biomass Production Program component which deals with such forest-oriented subjects as inventory, harvesting technology, silviculture and environmental impacts. (The other component, Biomass Conversion, deals with the technology of converting biomass to energy or fuels, and is administered by the Renewable Energy Branch of the Department of Energy, Mines and Resources.) Most biomass production projects, although developed by CFS scientists in the light of ENFOR program objectives, are carried under contract by forestry consultants and research specialists. Contractors are selected in accordance with science procurement tendering procedures of the Department of Supply and Services. For further information on the ENFOR Biomass Production Program, contact:

ENFOR Secretariat
Canadian Forestry Service
Envirionment Canada
Ottawa, Ontario
K1A 1G5

... or a CFS research laboratory.

This report is based on ENFOR projects P-112 and P-190 which were carried out under contracts (DSS File Nos. 97SC.KL001-9-0009 and 07SC.KL00L-1-0016) by Northland Associates Limited of St. John's, Newfoundland.

ABSTRACT

Equations to predict masses of tree components were prepared for seven species common to the island of Newfoundland. Equations that are applicable to regions of the Island and to the whole Island are provided. Breast-height diameter and total height were combined for use as the predictor variable.

RÉSUMÉ

Des équations ont été préparées pour la prévision des masses des parties constitutives de l'arbre pour sept essences ordinaires de l'île de Terre-Neuve. Des équations applicables tant aux différentes régions qu'à la totalité de l'île sont fournies. Le diamètre à hauteur de poitrine et la hauteur totale ont été combinés pour servir de variable de prévision.

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INTRODUCTION

Tree mass equations were prepared for species that are common to the island of Newfoundland. The ENFOR program instigated and supported development of tree mass equations in anticipation of the need by forest resource managers and policy makers for information about potential energy supplies from forests. Equations are suitable for use in place of volume equations for the Province (Page *et al.*, 1971; K[illegible], 1974), when estimates of tree mass are required.

Contractors responsible to the Newfoundland Forest Research Centre (NeFRC) collected data for tree mass equations. Data were collected throughout the Island, excepting the Northern Peninsula. A previous publiction (Lavigne and van Nostrand, 1981) reported equations for central Newfoundland. Data for central Newfoundland were reanalyzed and results presented in this report supercede the earlier publication.

Seven tree species were sampled for above-ground mass. These species were balsam fir *(abies balsamea* (L.) Mill.), black spruce *(Picea mariana* (Mill.) B.S.P.), white spruce *(P. glauca* (Moench) Voss), larch *(Larix laricina* (Du Roi) K. Koch), white birhc *(Betula papyrifera* Marsh.), yellow birch *(B. allegheniensis* Britton), and trembling aspen *(Populus tremuloides* Michx.). Trees smaller than current merchantable standards were measured for mass. However, trees shorter than 1.3 m were not sampled. The combination of field, laboratory and computation procedures permitted estimation of oven-dried masses of bole-wood, bole-bark, foliage + twigs, and branches for each tree.

Coefficeints of equations were estimated by weighted linear least squares regression. Predictor variables were diameter at breast height and total height. Equations were prepared for western, central and eastern Newfoundland. In addition, equations applicable to the whole Island and useful for more general applications were fit by combining regional data.

METHODS

Field and Laboratory Procedures

Northland Associates Ltd. performed field and laboratory work under contracts supervised by the Newfoundland Forest Research Centre. Contracts specified procedures for selecting and measuring mass of trees. Field methods were based on those of Alemdag (1980) and Ker (1980). The contractor delivered data required for computation of ovendried masses of components of sampled trees and NeFRC was responsible for all data analyses. Details of field and laboratory procedures prescribed to the contractor are copied in Appendix II. The information in Appendix II is identical to that provided in the earlier report (Lavigne and van Nostrand, 1981) and is reprinted here as a convenience to interested readers.

Central, western and eastern regions of Newfoundland were sampled respectively during three consecutive field seasons, beginning in 1979. Table 1 summarizes sampling of species in regions of the Island. Trees were collected on productive forest land and from stands scattered throughout each region.

Table 1. Species and geographic distribution of tree mass sampling.

Region	Forest Section *	Species
Central	B.28a	balsam fir black spruce white spruce larch white birch trembling aspen
West	B.28b	balsam fir black spruce white spruce larch white birch yellow birch
East	B.30	balsam fir black spruce white spruce larch white birch

*Rowe, J.S. 1972. Forest Regions of Canada. Dept. Environ. Can. For. Serv. Publ. No. 1300.

Species composition, site quality, and age class of stands were the criteria used to stratify the forest area for sampling. Provincial forest management inventory classification schemes (Anonymous, 1977) defined these stand characteristics. Data sets included trees from stands of as many combinations of site quality and age class as could be found in the region (see Appendix II for definitions of strata).

Stands that included balsam fir, black spruce, white birch and trembling aspen were located by using maps of the provincial forest management inventory. Inventory maps were suitable for the first phase of locating sample positions because these species comprised a noteworthy proportion of many stands. Stands with potential for sampling were found by scanning inventory maps or consulting stand lists generated from computer-based data banks. Stands were visited to determine their suitablity for sampling.

White spruce, larch and yellow birch comprise a small proportion of trees in any stand, or are found in isolated stands that were too small to be recognized by the forest management inventory. Sampling locations for these species could not be found by scanning inventory maps. Samples were collected when encountered in stand visited to harvest representatives of other species or whenever stands of these species were found. Information from surveys by the Newfoundland Forest Research Centre and foresters knowledgeable of the region contributed to locating stands containing these species.

Three to five trees from a stand were measured for mass. Trees were chosen from the range of breast-height diameters found in the stand. Field work in a stand was usually accomplished in one-half or one full day, so that it was rarely necessary to return to a stand. Effective use of field crews could be made by locating and visiting stands well in advance of harvesting sample trees.

Fresh masses of major tree components were measured in the field. Major tree componenets were bole (wood and bark), foliage + twigs, and branches. Samples of components were collected from every sample tree and carried to the laboratory. Fresh mass of component samples were measured with a precision balance on the same day as collected. Stem discs were separated into wood and bark for weighing and oven-drying. At a later date, samples were oven-dried and reweighed. Ratios of oven-dried to fresh masses were calculated for each component. The product of total fresh mass and ratio of oven-dried to fresh mass estimated oven-dried component masses for sampled trees.

Analysis

Seventeen data sets were collected for seven species in three regions of the Island. Five additional data sets were created by combining regional data sets for species sampled throughout the Island.

Previous work to develop tree mass equations in Newfoundland (Lavigne and van Nostrand, 1981) suggested using D^2H* as independent variable of prediction equations and weighted linear least squares to estimate coefficients. Preliminary analysis indicated that relationships between mass and the independent variable were frequently curvilinear. A sequence of two lines predicted component masses, to account for curvilinearity. The model for predicting mass of components was

$$\hat{Y} = \begin{cases} b_0 + b_1 \cdot D^2H & \text{if } D^2H \leq c \\ = b_0 + b_1 \cdot c + b_2 \cdot (D^2H - c) & \text{if } D^2H > c \end{cases} \quad \text{Eq.1}$$

where Y = component mass

c = point of interesection

b_0, b_1, b_2 = coefficients estimated by regression

Equation 1 was fit for every component of all species. The sequence of tasks performed with each data set included estimating weighting factors for each component, determining a point of intersection for use with all components of a data set, performing regression analyses, and adjusting coefficients of some equations to make predicted sum of components equal to predicted totals. Following is a description of each task of the sequence.

Weighted regression accounted for heterogeneous variance. Conditional var-

---

*Breast-height diameter^2 x total height.

iance of unweighted observations was assumed proportional to a function of the independent variable. This assumption was satisfactory for determining weights during previous work to construct tree mass and tree volume equations (Lavigne and van Nostrand, 1981; Cunia, 1979, 1964; Schreuder and Swank, 1973; Schumacher and Chapman, 1954). The relationship that was assumed between unweighted variance and the independent variable was

$$\text{var}(Y_i) \propto (D^2H_i)^k$$

where var (Y_i) is the conditional variance of component mass, given D^2H.

Procedures described by Schreuder and Swank (1973) were used to estimate the weighting factor, k, from sample data. A value for the weighting factor was estimated for each component. To estimate values of k, data sets were subdivided into 10 to 15 D^2H classes, variances were calculated from component masses in each subset, and logarithms of variances from D^2H. A value for k was given by the coefficient that estimated slope. A weight was calculated for each observation as

$$w = (D^2H)^{-k}$$

Procedures for including weights in regression analyses are described by Dixon (1981) for the BMDP statistics programs. Draper and Smith (1981) described weighted regression for the general case, and Cunia (1964) discussed applications of weighted regression to construction of volume operations.

A point of intersection was calculated for the lines predicting total oven-dried mass and then was used to fit Equation 1 for all other components. The point of intersection was estimated by nonlinear regression fit of the model

$$\hat{Y} = b_0 + b_1 * D^2H + b_2 * \text{AMIN}(D^2H, c) \quad \text{Eq. 2}$$

where Y = total oven-dried mass

AMIN = FORTRAN function that chooses the smaller of two arguments

c = a parameter calculated by regression that estimates the point of intersection

Equation 2 was fitted by BMDPAR program of the BMDP statistical package (Dixon, 1981).

Weighted linear regression calculations fit equations predicting mass of components. The BMDPIR program of BMDP was used (Dixon, 1981). This program can incorporate functions from the FORTRAN library which facilitated calculation of two slopes for lines intersecting at a known point. For these computations Equation 1 was rewritten as

$$\hat{Y} = b_0 + b_1 * \text{AMIN}(D^2H, c) + b_2 * \text{AMAX}(0, D^2H - c) \quad \text{Eq. 3}$$

where AMIN = a FORTRAN function that chooses the smaller of two arguments.

AMAX = a FORTRAN function that chooses the larger of two arguments

Predictions for component masses did not necessarily sum to prediction of total mass. The coefficients of some equations were adjusted to make predictions for component masses sum to predicted total mass. Coefficients of equations for the bole-bark were adjusted to make predicted sum of bole-wood and bole-bark equal predicted bole mass. Equations predicting oven-dried mass of foliage + twigs were adjusted to make sum of major components equal total oven-dried mass.

TREE MASS EQUATIONS

Predictions from equations fit by regression are most reliable when applied to the area where data were collected and when future observations of predictor variables are within the range of data used to estimate coefficients. The geographic distribution of sampling for tree mass equations is shown in Figure 1. Ranges of independent variables and component masses for sampled trees are listed in Table 2.

Sampling methods directed that data be collected from many stands. Measurements of mass were made for trees with a wide range of combinations of breast-height diameter and total height. Data sets contained replicate samples in classes of independent variables for trees that differed with respect to age, crown class and site quality. Methods for selecting sample trees were designed to yield data sets that represented the range of variability of component masses among trees of the region.

Tree mass prediction equations were prepared for central (Table 3), western (Table 4) and eastern (Table 5) regions, and for the whole Island (Table 6). To contrast predictions for regions, equations and observations of a component for all areas were plotted together. Relative variation between regions was least for predictions of bole mass and greatest for predictions of mass of crown components. Regional differences were least for balsam fir and black spruce for predictions of all component masses. For larch, white spruce and white birch regional differences were considerable for predictions of all components. Use of regional equations is recommended wherever possible, and especially when applied to data from a single area of the Island. Equations for the whole Island are most suitable for easier, but less accurate, estimation based on aggregate data from diverse locations.

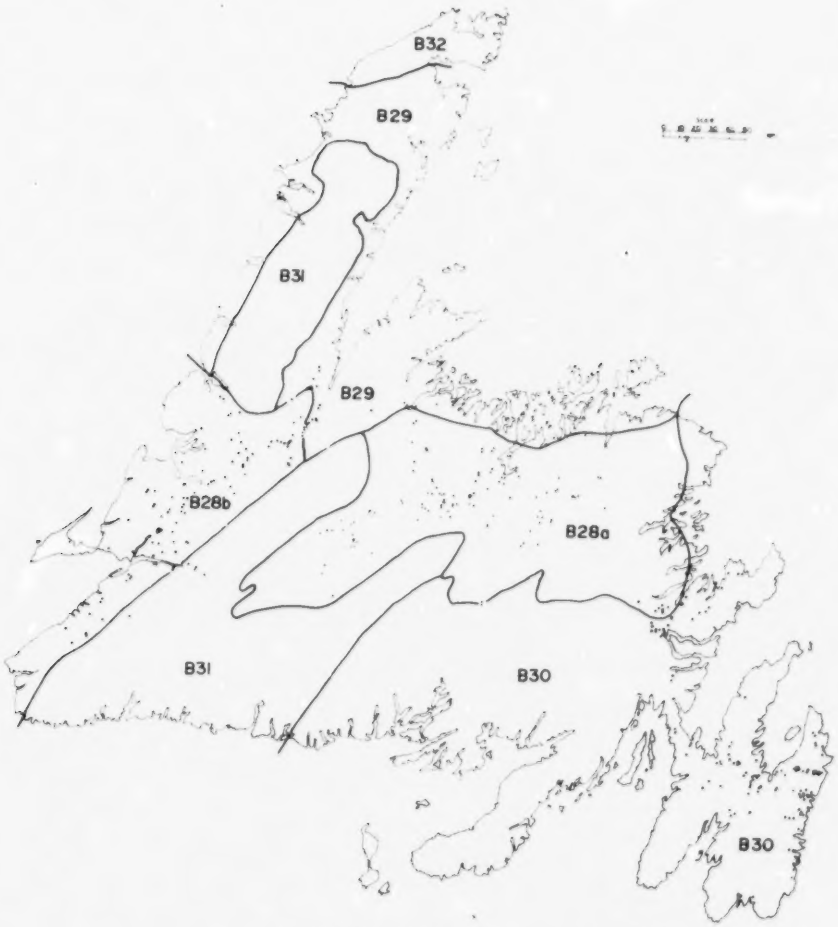

Figure 1. Stand locations for tree mass sampling.

Table 2. Summary statistics of tree mass data collected throughout Newfoundland

Species	Region	No. of samples	DBH cm	Height m	Total O.D. mass	Bole O.D. mass	Branches O.D. mass	Fol. + twigs O.D.mass
					kg			
balsam fir	west	97	2.1-32.7	2.3-19.1	.7-328.9	.3-230.4	0-73.0	.2-73.9
	central	73	1.5-29.7	1.9-17.9	.6-302.0	.3-194.3	0-54-2	.3-56.4
	east	126	1.9-29.8	2.1-16.5	.9-314.6	0-185.1	0-86.6	.4-50.4
	total	296	1.5-32.7	1.9-19.1	.6-328.9	0-230.4	0-86.6	.2-73.9
black spruce	west	80	1.2-28.9	1.9-20.6	1.1-332.7	0-267.6	0-69.1	0-62.0
	central	98	2.3-28.6	1.9-18.1	2.8-277.7	.4-206.9	0-51.4	.2-40.9
	east	140	1.3-28.8	1.9-15.8	1.0-323.9	0-201.0	.1-80.6	.2-42.2
	total	318	1.2-28.9	1.9-20.6	1.0-332.7	0-267.6	0-80.6	0-62.0
white spruce	west	57	1.8-31.3	2.1-18.3	1.3-360.2	.5-229.6	0-71.5	.4-59.1
	central	53	3.0-30.5	2.8-18.0	1.9-347.2	.9-248.5	.2-54.2	.8-63.1
	east	59	2.1-28.0	2.1-13.9	1.8-290.6	.5-136.2	0-76.4	1.1-78.1
	total	169	1.8-31.3	2.1-18.3	1.3-360.2	.5-248.5	0-76.4	.4-78.1
larch	west	83	1.5-21.3	2.6-17.4	.5-167.9	.4-138.1	0-29.2	0-12.2
	central	60	1.3-29.2	2.1-20.9	.4-273.5	.1-245.6	0-35.0	.3-11.4
	east	100	1.9-19.0	2.2-15.5	.8-113.5	0-82.4	0-25.1	.1-18.1
	total	243	1.3-29.2	2.1-20.9	.4-273.5	0-245.6	0-35.0	0-18.1
white birch	west	89	2.0-34.3	2.8-17.6	1.0-491.4	.5-329.7	0-176.7	.2-42.4
	central	68	2.1-28.3	2.6-18.9	.9-431.6	.5-307.7	.1-131.7	.2-35.9
	east	118	1.9-28.1	2.6-14.4	.9-288.1	0-180.7	0-91.0	.2-27.1
	total	275	1.9-34.3	2.6-18.9	.9-491.4	0-329.7	0-176.7	.2-42.4
yellow birch	west	53	2.2-43.0	2.9-20.0	1.9-1223.5	.8-757.6	.4-403.0	.4-62.9
trembling aspen	central	70	2.2-44.7	3.3-23.4	.7-764.2	.5-693.7	0-79.5	0-19.2

The degree of fit of equations to sample data can be judged by considering coefficients of determination in Tables 3-6 and by examining plots of residuals in Appendix I. Residuals are plotted against the independent variable to provide an indication of reliability of predictions over the range of the predictor variable. Decisions to use weighted least square methods and prediction equations comprised of two lines were based largely on examination of plots of residuals.

Coefficients of equations predicting masses of bark, and foliage + twigs were adjusted. As a result sum of predicted masses of wood and bark equal predicted bole mass, and sum of predicted masses of bole, branches, and foliage + twigs equal predicted total mass for any value of the independent variable.

Table 3. Tree mass equations for central Newfoundland.
Units: component = kg; D = cm; H = m

Component	Equations		R^2	var (Y)
	balsam fir (n = 73)			
Total	$1.13020 + .02339\ D^2H$	if $D^2H \leq 976$	.9654	$.8966\ D^2H^{1.3244}$
	$1.13020 + .02339\ (976) + .018960\ (D^2H - 976)$	if $D^2H > 976$		
Bole	$.27507 + .01657\ D^2H$	if $D^2H \leq 976$	.9811	$.0871\ D^2H^{1.5016}$
	$.27507 + .01657\ (976) + .014474\ (D^2H - 976)$	if $D^2H > 976$		
Wood	$.14397 + .015609\ D^2H$	if $D^2H \leq 976$	.9869	$.02379\ D^2H^{1.6943}$
	$.14397 + .015609\ (976) + .011846\ (D^2H - 976)$	if $D^2H > 976$		
Bark*	$.13110 + .000961\ D^2H$	if $D^2H \leq 976$	.9167	$.00652\ D^2H^{1.6625}$
	$.13110 + .000961\ (976) + .002628\ (D^2H - 976)$	if $D^2H > 976$		
Branches	$-.01782 + .0026489\ D^2H$	if $D^2H \leq 976$	.8186	$.0318\ D^2H^{1.5020}$
	$-.01782 + .0026489\ (976) + .0026664\ (D^2H - 976)$	if $D^2H > 976$		
Fol. & Twigs*	$.87295 + .0041711\ D^2H$	if $D^2H \leq 976$	.6758	$.7215\ D^2H^{1.0840}$
	$.87295 + .0041711\ (976) + .0018196\ (D^2H - 976)$	if $D^2H > 976$		
	white spruce (n = 53)			
Total	$1.70135 + .03048\ D^2H$	if $D^2H \leq 1375$	.9821	$16.7966\ D^2H^{.8648}$
	$1.70135 + .03048\ (1375) + .021084\ (D^2H - 1375)$	if $D^2H > 1375$		
Bole	$.38577 + .01928\ D^2H$	if $D^2H \leq 1375$	.9803	$1.1538\ D^2H^{1.3648}$
	$.38577 + .01928\ (1375) + .015199\ (D^2H - 1375)$	if $D^2H > 1375$		
Wood	$.31670 + .01659\ D^2H$	if $D^2H \leq 1375$	.9804	$.35037\ D^2H^{1.6136}$
	$.31670 + .01659\ (1375) + .013918\ (D^2H - 1375)$	if $D^2H > 1375$		
Bark*	$.06907 + .00269\ D^2H$	if $D^2H \leq 1375$	.9676	$.02030\ D^2H^{1.4650}$
	$.06907 + .00269\ (1375) + .001281\ (D^2H - 1375)$	if $D^2H > 1375$		
Branches	$.17017 + .0050745\ D^2H$	if $D^2H \leq 1375$	.8079	$1.0422\ D^2H^{1.2850}$
	$.17017 + .0050745\ (1375) + .0032649\ (D^2H - 1375)$	if $D^2H > 1375$		
Fol. & Twigs*	$1.14541 + .0061255\ D^2H$	if $D^2H \leq 1375$	.8052	$12.8711\ D^2H^{.5560}$
	$1.14541 + .0061255\ (1375) + .0026201\ (D^2H - 1375)$	if $D^2H > 1375$		
	black spruce (n = 98)			
Total	$3.20112 + .03310\ D^2H$	if $D^2H \leq 124$	.9552	$5.6720\ D^2H^{1.2044}$
	$3.20112 + .03310\ (124) + .023435\ (D^2H - 124)$	if $D^2H > 124$		
Bole	$.61801 + .02095\ D^2H$	if $D^2H \leq 124$	.9854	$.8130\ D^2H^{1.2636}$
	$.61801 + .02095\ (124) + .018473\ (D^2H - 124)$	if $D^2H > 124$		
Wood	$.44123 + .01796\ D^2H$	if $D^2H \leq 124$	.9886	$.72535\ D^2H^{1.1937}$
	$.44123 + .01796\ (124) + .016239\ (D^2H - 124)$	if $D^2H > 124$		
Bark*	$.17678 + .00299\ D^2H$	if $D^2H \leq 124$	.9660	$.09360\ D^2H^{1.0397}$
	$.17678 + .00299\ (124) + .002234\ (D^2H - 124)$	if $D^2H > 124$		
Branches	$.37765 + .00072219\ D^2H$	if $D^2H \leq 124$	.6238	$.9683\ D^2H^{1.2592}$
	$.37765 + .00072219\ (124) + .0032289\ (D^2H - 124)$	if $D^2H > 124$		
Fol. & Twigs*	$2.20546 + .0114279\ D^2H$	if $D^2H \leq 124$	.4495	$7.4257\ D^2H^{.7922}$
	$2.20546 + .0114279\ (124) + .0017331\ (D^2H - 124)$	if $D^2H > 124$		

larch (n = 60)				
Total	$.42636 + .03113\ D^2H$	if $D^2H \leq 789$	.9818	$5.6221\ D^2H^{.9264}$
	$.42636 + .03113\ (789) + .018246\ (D^2H - 789)$	if $D^2H > 789$		
Bole	$.01871 + .02315\ D^2H$	if $D^2H \leq 789$	.9853	$1.1931\ D^2H^{1.0896}$
	$.01871 + .02315\ (789) + .015575\ (D^2H - 789)$	if $D^2H > 789$		
Wood	$-.00904 + .01947\ D^2H$	if $D^2H \leq 789$	.9807	$.08600\ D^2H^{1.5088}$
	$-.00904 + .01947\ (789) + .014360\ (D^2H - 789)$	if $D^2H > 789$		
Bark*	$.02775 + .00368\ (D^2H)$	if $D^2H \leq 789$	.9754	$.13529\ D^2H^{.8243}$
	$.02775 + .00368\ (789) + .001215\ (D^2H - 789)$	if $D^2H > 789$		
Branches	$-.01413 + .0043561\ D^2H$	if $D^2H \leq 789$	.8068	$.2977\ D^2H^{1.1860}$
	$-.01413 + .0043561\ (789) + .0024327\ (D^2H - 789)$	if $D^2H > 789$		
Fol. & Twigs*	$.42178 + .0036239\ D^2H$	if $D^2H \leq 789$	.5729	$1.8967\ D^2H^{.5256}$
	$.42178 + .0036239\ (789) + .0002383\ (D^2H - 789)$	if $D^2H > 789$		
white birch (n = 68)				
Total	$.51064 + .04111\ D^2H$	if $D^2H \leq 91$	.9763	$8.1189\ D^2H^{1.2070}$
	$.51064 + .04111\ (91) + .026999\ (D^2H - 91)$	if $D^2H > 91$		
Bole	$.17979 + .02709\ D^2H$	if $D^2H \leq 91$	.9865	$1.8324\ D^2H^{1.3000}$
	$.17979 + .02709\ (91) + .021817\ (D^2H - 91)$	if $D^2H > 91$		
Wood	$.10305 + .02276\ D^2H$	if $D^2H \leq 91$	.9863	$.5752\ D^2H^{1.4591}$
	$.10305 + .02276\ (91) + .018469\ (D^2H - 91)$	if $D^2H > 91$		
Bark*	$.07674 + .00433\ D^2H$	if $D^2H \leq 91$	.9665	$.0176\ D^2H^{1.6580}$
	$.07674 + .00433\ (91) + .003348\ (D^2H - 91)$	if $D^2H > 91$		
Branches	$.05217 + .00640\ D^2H$	if $D^2H \leq 91$	.6994	$.1143\ D^2H^{1.8100}$
	$.05217 + .00640\ (91) + .0036464\ (D^2H - 91)$	if $D^2H > 91$		
Fol. & Twigs*	$.27868 + .00762\ D^2H$	if $D^2H \leq 91$	.6616	$.6142\ D^2H^{1.1380}$
	$.27868 + .00762\ (91) + .0015356\ (D^2H - 91)$	if $D^2H > 91$		
trembling aspen (n = 70)				
Total	$.38022 + .02348\ D^2H$	if $D^2H \leq 409$	.9856	$1.6893\ D^2H^{1.4000}$
	$.38022 + .02348\ (409) + .019903\ (D^2H - 409)$	if $D^2H > 409$		
Bole	$.18968 + .01831\ D^2H$	if $D^2H \leq 409$	.9912	$.4275\ D^2H^{1.5000}$
	$.18968 + .01831\ (409) + .017034\ (D^2H - 409)$	if $D^2H > 409$		
Wood	$.09496 + .01497\ D^2H$	if $D^2H \leq 409$	.9903	$.0827\ D^2H^{1.7552}$
	$.09496 + .01497\ (409) + .014131\ (D^2H - 409)$	if $D^2H > 409$		
Bark*	$.09472 + .00334\ D^2H$	if $D^2H \leq 409$	.9669	$.0678\ D^2H^{1.8827}$
	$.09472 + .00334\ (409) + .002903\ (D^2H - 409)$	if $D^2H > 409$		
Branches	$-.04606 + .0023230\ D^2H$	if $D^2H \leq 409$	.7885	$.0488\ D^2H^{1.8000}$
	$-.04606 + .0023230\ (409) + .0024167\ (D^2H - 409)$	if $D^2H > 409$		
Fol. & Twigs*	$.23660 + .002847\ D^2H$	if $D^2H \leq 409$	.5850	$.3641\ D^2H^{1.1380}$
	$.23660 + .002847\ (409) + .0004523\ (D^2H - 409)$	if $D^2H > 409$		

*Coefficients adjusted to make predictions additive.

Table 4. Tree mass equations for western Newfoundland.
Units: component = kg; D = cm; H = m

Component	Equations		R^2	var (Y)
	balsam fir (n = 97)			
Total	$.69040 + .02836\ D^2H$	if $D^2H \leq 403$	.9804	$1.5520\ D^2H^{1.2980}$
	$.69040 + .02836\ (403) + .019366\ (D^2H - 403)$	if $D^2H > 403$		
Bole	$.20087 + .01859\ D^2H$	if $D^2H \leq 403$	.9846	$.5471\ D^2H^{1.3222}$
	$.20087 + .01859\ (403) + .014081\ (D^2H - 403)$	if $D^2H > 403$		
Wood	$.12659 + .01571\ D^2H$	if $D^2H \leq 403$	.9849	$.3120\ D^2H^{1.3600}$
	$.12659 + .01571\ (403) + .011937\ (D^2H - 403)$	if $D^2H > 403$		
Bark*	$.07429 + .00288\ D^2H$	if $D^2H \leq 403$	.9418	$.0409\ D^2H^{1.3615}$
	$.07429 + .00288\ (403) + .002144\ (D^2H - 403)$	if $D^2H > 403$		
Branches	$.00727 + .0028505\ D^2H$	if $D^2H \leq 403$	.8296	$.0291\ D^2H^{1.7188}$
	$.00727 + .0028505\ (403) + .0028211\ (D^2H - 403)$			
Fol. + Twigs*	$.48226 + .0069195\ D^2H$	if $D^2H \leq 403$	.7893	$1.2944\ D^2H^{1.0834}$
	$.48226 + .0069195\ (403) + .0024638\ (D^2H - 403)$	if $D^2H > 403$		
	white spruce (n = 57)			
Total	$2.27015 + .03198\ D^2H$	if $D^2H \leq 958$	.9824	$10.0383\ D^2H^{.7132}$
	$2.27015 + .03198\ (958) + .020590\ (D^2H - 958)$	if $D^2H > 958$		
Bole	$.42512 + .018436\ D^2H$	if $D^2H \leq 958$	.9782	$3492\ D^2H^{1.2836}$
	$.42512 + .018436\ (958) + .015396\ (D^2H - 958)$	if $D^2H > 958$		
Wood	$.33063 + .016033\ D^2H$	if $D^2H \leq 958$	.9778	$.2221\ D^2H^{1.3274}$
	$.33063 + .016033\ (958) + .013776\ (D^2H - 958)$	if $D^2H > 958$		
Bark*	$.09449 + .002403\ D^2H$	if $D^2H \leq 958$	.9579	$.0273\ D^2H^{1.0625}$
	$.09449 + .002403\ (958) + .00162\ (D^2H - 958)$	if $D^2H > 958$		
Branches	$.27709 + .0030990\ D^2H$	if $D^2H \leq 958$	.8841	$.5517\ D^2H^{.8990}$
	$.27709 + .0030990\ (958) + .0030822\ (D^2H - 958)$	if $D^2H > 958$		
Fol. + Twigs	$1.56794 + .010455\ D^2H$	if $D^2H \leq 958$	.7304	$4.7519\ D^2H^{.7729}$
	$1.56794 + .010455\ (958) + .0021118\ (D^2H - 958)$	if $D^2H > 958$		
	black spruce (n = 80)			
Total	$.92586 + .05665\ D^2H$	if $D^2H \leq 148$	.9439	$2.2217\ D^2H^{1.2469}$
	$.92586 + .05665\ (148) + .023449\ (D^2H - 148)$	if $D^2H > 148$		
Bole	$-.02773 + .03061\ D^2H$	if $D^2H \leq 148$	.9810	$.4455\ D^2H^{1.2012}$
	$-.02773 + .03061\ (148) + .016571\ (D^2H - 148)$	if $D^2H > 148$		
Wood	$-.03479 + .02567\ D^2H$	if $D^2H \leq 148$	.9793	$.3168\ D^2H^{1.2235}$
	$-.03479 + .02567\ (148) + .014373\ (D^2H - 148)$	if $D^2H > 148$		
Bark*	$.00706 + .00494\ D^2H$	if $D^2H \leq 148$	.9484	$.0123\ D^2H^{1.3070}$
	$.00706 + .00494\ (148) + .002198\ (D^2H - 148)$	if $D^2H > 148$		
Branches	$.17719 + .00889\ D^2H$	if $D^2H \leq 148$	.6287	$2.6263\ D^2H^{.9886}$
	$.17719 + .00889\ (148) + .0037900\ (D^2H - 148)$	if $D^2H > 148$		
Fol. + Twigs*	$.77640 + .01715\ D^2H$	if $D^2H \leq 148$	.7310	$1.4233\ D^2H^{.9805}$
	$.77640 + .01715\ (148) + .003088\ (D^2H - 148)$	if $D^2H > 148$		

larch (n = 83)				
Total	$.44363 + .03162\ D^2H$	if $D^2H \leq 494$	.9762	$.4829\ D^2H^{1.3977}$
	$.44363 + .03162\ (494) + .022640\ (D^2H - 494)$	if $D^2H > 494$		
Bole	$.22932 + .020469\ D^2H$	if $D^2H \leq 494$	.9758	$.0489\ D^2H^{1.7504}$
	$.22932 + .020469\ (494) + .018534\ (D^2H - 494)$	if $D^2H > 494$		
Wood	$.13959 + .017784\ D^2H$	if $D^2H \leq 494$	.9714	$.0307\ D^2H^{1.8312}$
	$.13959 + .017784\ (494) + .016584\ (D^2H - 494)$	if $D^2H > 494$		
Bark*	$.08973 + .002685\ D^2H$	if $D^2H \leq 494$	.9774	$.0048\ D^2H^{1.3217}$
	$.08973 + .002685\ (494) + .001950\ (D^2H - 494)$	if $D^2H > 494$		
Branches	$.00184 + .0063816\ D^2H$	if $D^2H \leq 494$	.7993	$.3015\ D^2H^{1.2186}$
	$.00184 + .0063816\ (494) + .0031740\ (D^2H - 494)$	if $D^2H > 494$		
Fol. + Twigs*	$.21247 + .0047694\ D^2H$	if $D^2H \leq 494$	.6463	$.4087\ D^2H^{.9727}$
	$.21247 + .0047694\ (494) + .000932\ (D^2H - 494)$	if $D^2H > 494$		
white birch (n = 89)				
Total	$.71667 + .030571\ D^2H$		.9631	$1.9484\ D^2H^{1.5160}$
Bole	$.44680 + .021884\ D^2H$		.9833	$1.7299\ D^2H^{1.2445}$
Wood	$.33997 + .018655\ D^2H$		.9812	$1.1729\ D^2H^{1.2822}$
Bark*	$.10683 + .003229\ D^2H$		.9661	$.1197\ D^2H^{1.1556}$
Branches	$.05334 + .0056438\ D^2H$		.6323	$.1183\ D^2H^{1.9522}$
Fol. + Twigs*	$.21653 + .0030432\ D^2H$		.6622	$.6525\ D^2H^{1.1425}$
yellow birch (n = 53)				
Total	$1.43611 + .029656\ D^2H$		.9724	$1.3380\ D^2H^{1.6298}$
Bole	$.51280 + .020224\ D^2H$		.9848	$.5758\ D^2H^{1.5046}$
Wood	$.43466 + .017357\ D^2H$		.9853	$.4099\ D^2H^{1.5038}$
Bark*	$.07814 + .002867\ D^2H$		.9479	$.0421\ D^2H^{1.5340}$
Branches	$.40984 + .0069046\ D^2H$		.8238	$.2535\ D^2H^{1.8290}$
Fol. + Twigs*	$.42491 + .0025274\ D^2H$		.8305	$.2887\ D^2H^{1.4534}$

*Coefficients adjusted to make predictions additive.

Table 5. Tree mass equations for eastern Newfoundland.
Units: component = kg; D = cm; H = m

Component	Equations		R^2	var (Y)
	balsam fir (n = 126)			
Total	$.88230 + .03318\ D^2H$	if $D^2H \leq 772$	.9589	$1.7176\ D^2H^{1.2487}$
	$.88230 + .03318\ (772) + .018483\ (D^2H - 772)$	if $D^2H > 772$		
Bole	$.24906 + .016984\ D^2H$	if $D^2H \leq 772$	.9860	$.2932\ D^2H^{1.1859}$
	$.24906 + .016984\ (772) + .013329\ (D^2H - 772)$	if $D^2H > 772$		
Wood	$.15284 + .014628\ D^2H$	if $D^2H \leq 772$	.9859	$.1350\ D^2H^{1.2874}$
	$.15284 + .014628\ (772) + .011227\ (D^2H - 772)$	if $D^2H > 772$		
Bark*	$.09622 + .002356\ D^2H$	if $D^2H \leq 772$	.9542	$.0532\ D^2H^{1.0006}$
	$.09622 + .002356\ (772) + .002102\ (D^2H - 772)$	if $D^2H > 772$		
Branches	$.12979 + .0044864\ D^2H$	if $D^2H \leq 772$	.7749	$.1770\ D^2H^{1.3529}$
	$.12979 + .0044864\ (772) + .0032124\ (D^2H - 772)$	if $D^2H > 772$		
Fol. + Twigs*	$.50345 + .0117096\ D^2H$	if $D^2H \leq 772$	.6921	$.8379\ D^2H^{1.3048}$
	$.50345 + .0117096\ (772) + .0019416\ (D^2H - 772)$	if $D^2H > 772$		
	white spruce (n = 59)			
Total	$.76697 + .13466\ D^2H$	if $D^2H \leq 42$	.9093	$5.8626\ D^2H^{1.1895}$
	$.76697 + .13466\ (42) + .02746\ (D^2H - 42)$	if $D^2H > 42$		
Bole	$.41556 + .03062\ D^2H$	if $D^2H \leq 42$	.9759	$.2874\ D^2H^{1.2854}$
	$.41556 + .03062\ (42) + .016253\ (D^2H - 42)$	if $D^2H > 42$		
Wood	$.23448 + .02768\ D^2H$	if $D^2H \leq 42$	.9800	$.1784\ D^2H^{1.2900}$
	$.23448 + .02768\ (42) + .014223\ (D^2H - 42)$	if $D^2H > 42$		
Bark*	$.18108 + .00294\ D^2H$	if $D^2H \leq 42$	.9248	$.0290\ D^2H^{1.1337}$
	$.18108 + .00294\ (42) + .00203\ (D^2H - 42)$	if $D^2H > 42$		
Branches	$-.05851 + .01862\ D^2H$	if $D^2H \leq 42$	.7412	$.1993\ D^2H^{1.5743}$
	$-.05851 + .01862\ (42) + .0067424\ (D^2H - 42)$	if $D^2H > 42$		
Fol. + Twigs*	$.40992 + .08542\ D^2H$	if $D^2H \leq 42$	.6087	$4.3566\ D^2H^{.9525}$
	$.40992 + .08542\ (42) + .0044646\ (D^2H - 42)$	if $D^2H > 42$		
	black spruce (n = 140)			
Total	$2.16122 + .03953\ D^2H$	if $D^2H \leq 312$	.9743	$5.7031\ D^2H^{.9340}$
	$2.16122 + .03953\ (312) + .022664\ (D^2H - 312)$	if $D^2H > 312$		
Bole	$.14621 + .02449\ D^2H$	if $D^2H \leq 312$	.9874	$.4627\ D^2H^{1.1506}$
	$.14621 + .02449\ (312) + .017077\ (D^2H - 312)$	if $D^2H > 312$		
Wood	$.06925 + .020898\ D^2H$	if $D^2H \leq 312$	.9881	$.2548\ D^2H^{1.2007}$
	$.06925 + .020898\ (312) + .015161\ (D^2H - 312)$	if $D^2H > 312$		
Bark*	$.07696 + .003592\ D^2H$	if $D^2H \leq 312$	.9533	$.0609\ D^2H^{.9860}$
	$.07696 + .003592\ (312) + .001916\ (D^2H - 312)$	if $D^2H > 312$		
Branches	$.45784 + .00477\ D^2H$	if $D^2H \leq 312$	.7881	$.2953\ D^2H^{1.1925}$
	$.45784 + .00477\ (312) + .0033505\ (D^2H - 312)$	if $D^2H > 312$		
Fol. + Twigs*	$1.55717 + .014563\ D^2H$	if $D^2H \leq 312$	.6613	$3.2486\ D^2H^{.8184}$
	$1.55717 + .014563\ (312) + .0022365\ (D^2H - 312)$	if $D^2H > 312$		

	larch (n = 100)			
Total	$.73871 + .03405\ D^2H$	if $D^2H \leq 515$	.9677	$.5637\ D^2H^{1.3317}$
	$.73871 + .03450\ (515) + .024751\ (D^2H - 515)$	if $D^2H > 515$		
Bole	$.30240 + .021849\ D^2H$	if $D^2H \leq 515$	.9709	$.2306\ D^2H^{1.3381}$
	$.30240 + .021849\ (515) + .017939\ (D^2H - 515)$	if $D^2H > 515$		
Wood	$.19935 + .019044\ D^2H$	if $D^2H \leq 515$	.9689	$.1587\ D^2H^{1.3883}$
	$.19935 + .019044\ (515) + .016113\ (D^2H - 515)$	if $D^2H > 515$		
Bark*	$.10305 + .002805\ D^2H$	if $D^2H \leq 515$	.9622	$.0136\ D^2H^{1.0079}$
	$.10305 + .002805\ (515) + .001826\ (D^2H - 515)$	if $D^2H > 515$		
Branches	$.09420 + .0057616\ D^2H$	if $D^2H \leq 515$	.7593	$.0852\ D^2H^{1.5211}$
	$.09420 + .0057616\ (515) + .0048676\ (D^2H - 515)$	if $D^2H > 515$		
Fol. + Twigs*	$.34211 + .0064394\ D^2H$	if $D^2H \leq 515$	.7008	$.2547\ D^2H^{1.1362}$
	$.34211 + .0064394\ (515) + .0019444\ (D^2H - 515)$	if $D^2H > 515$		
	white birch (n = 118)			
Total	$.92517 + .033449\ D^2H$	if $D^2H \leq 1627$	.9607	$1.0712\ D^2H^{1.4308}$
	$.92517 + .033449\ (1627) + .02568\ (D^2H - 1627)$	if $D^2H > 1627$		
Bole	$.35753 + .023300\ D^2H$	if $D^2H \leq 1627$	.9750	$.3832\ D^2H^{1.3908}$
	$.35753 + .023300\ (1627) + .017466\ (D^2H - 1627)$	if $D^2H > 1627$		
Wood	$.27193 + .019552\ D^2H$	if $D^2H \leq 1627$	.9751	$.2474\ D^2H^{1.4115}$
	$.27193 + .019552\ (1627) + .014825\ (D^2H - 1627)$	if $D^2H > 1627$		
Bark*	$.08960 + .003748\ D^2H$	if $D^2H \leq 1627$	.9466	$.0288\ D^2H^{1.3201}$
	$.08560 + .003748\ (1627) + .002641\ (D^2H - 1627)$	if $D^2H > 1627$		
Branches	$.27023 + .0056691\ D^2H$	if $D^2H \leq 1627$	.6690	$.2458\ D^2H^{1.6252}$
	$.27023 + .0056691\ (1627) + .00787\ (D^2H - 1627)$	if $D^2H > 1627$		
Fol. + Twigs*	$.29741 + .0044799\ D^2H$	if $D^2H \leq 1627$	.6879	$.1837\ D^2H^{1.2661}$
	$.29741 + .0044799\ (1627) + .000344\ (D^2H - 1627)$	if $D^2H > 1627$		

*Coefficients adjusted to make predictions additive.

Table 6. Tree mass equations for the island of Newfoundland.
Units: component = kg; D = cm; H = m

Component	Equations		R^2	var (Y)
	balsam fir (n = 296)			
Total	$.92011 + .03160\ D^2H$	if $D^2H \leq 547$	.9696	$2.1734\ D^2H^{1.934}$
	$.92011 + .03160\ (547) + .018880\ (D^2H - 547)$	if $D^2H > 547$		
Bole	$.26022 + .017162\ D^2H$	if $D^2H \leq 547$	.9835	$.3259\ D^2H^{1.2952}$
	$.26022 + .017162\ (547) + .014146\ (D^2H - 547)$	if $D^2H > 547$		
Wood	$.10764 + .016938\ D^2H$	if $D^2H \leq 547$	.9821	$2.8619\ D^2H^{1.3444}$
	$.10764 + .016938\ (547) + .011943\ (D^2H - 547)$	if $D^2H > 547$		
Bark*	$.15258 + .000224\ D^2H$	if $D^2H \leq 547$	.9525	$.0160\ D^2H^{1.5432}$
	$.15258 + .000224\ (547) + .002203\ (D^2H - 547)$	if $D^2H > 547$		
Branches	$.03076 + .0042907\ D^2H$	if $D^2H \leq 547$	.7941	$.1346\ D^2H^{1.3822}$
	$.03076 + .0042907\ (547) + .0027838\ (D^2H - 547)$	if $D^2H > 547$		
Fol. + twigs*	$.62913 + .0101473\ D^2H$	if $D^2H \leq 547$	.6821	$2.1077\ D^2H^{.9953}$
	$.62913 + .0101473\ (547) + .0019502\ (D^2H - 547)$	if $D^2H > 547$		
	white spruce (n = 169)			
Total	$2.47518 + .03119\ D^2H$	if $D^2H \leq 1342$	.9538	$10.3010\ D^2H^{.9744}$
	$2.47518 + .03119\ (1342) + .021230\ (D^2H - 1342)$	if $D^2H > 1342$		
Bole	$.51481 + .018346\ D^2H$	if $D^2H \leq 1342$	.9783	$.3774\ D^2H^{1.3189}$
	$.51481 + .018346\ (1342) + .015154\ (D^2H - 1342)$	if $D^2H > 1342$		
Wood	$.37458 + .016216\ D^2H$	if $D^2H \leq 1342$	.9851	$.1520\ D^2H^{1.4756}$
	$.37458 + .016216\ (1342) + .013457\ (D^2H - 1342)$	if $D^2H > 1342$		
Bark*	$.14023 + .00213\ D^2H$	if $D^2H \leq 1342$	.9633	$.0071\ D^2H^{1.7185}$
	$.14023 + .00213\ (1342) + .001697\ (D^2H - 1342)$	if $D^2H > 1342$		
Branches	$.20061 + .0056664\ D^2H$	if $D^2H \leq 1342$	.6968	$.4420\ D^2H^{1.3605}$
	$.20061 + .0056664\ (1342) + .0035302\ (D^2H - 1342)$	if $D^2H > 1342$		
Fol. + twigs*	$1.75976 + .0071776\ D^2H$	if $D^2H \leq 1342$	.6464	$5.4613\ D^2H^{.8602}$
	$1.75976 + .0071776\ (1342) + .0025458\ (D^2H - 1342)$	if $D^2H > 1342$		
	black spruce (n = 318)			
Total	$1.73988 + .05292\ D^2H$	if $D^2H \leq 123$	.9614	$5.4310\ D^2H^{1.0581}$
	$1.73988 + .05292\ (123) + .023296\ (D^2H - 123)$	if $D^2H > 123$		
Bole	$.10336 + .02922\ D^2H$	if $D^2H \leq 123$	.9840	$.6722\ D^2H^{1.1598}$
	$.10336 + .02922\ (123) + .017495\ (D^2H - 123)$	if $D^2H > 123$		
Wood	$.05935 + .025401\ D^2H$	if $D^2H \leq 123$	.9863	$1.2670\ D^2H^{.9757}$
	$.05935 + .025401\ (123) + .015272\ (D^2H - 123)$	if $D^2H > 123$		
Bark*	$.04401 + .003819\ D^2H$	if $D^2H \leq 123$	.9850	$.0158\ D^2H^{1.4164}$
	$.04401 + .003819\ (123) + .002223\ (D^2H - 123)$	if $D^2H > 123$		
Branches	$.32143 + .00607\ D^2H$	if $D^2H \leq 123$	.7941	$.1346\ D^2H^{1.3822}$
	$.32143 + .00607\ (123) + .0034352\ (D^2H - 123)$	if $D^2H > 123$		
Fol. + twigs*	$1.31509 + .01763\ D^2H$	if $D^2H \leq 123$	.6096	$3.8221\ D^2H^{.8465}$
	$1.31509 + .01763\ (123) + .0023658\ (D^2H - 123)$	if $D^2H > 123$		

larch (n = 243)				
Total	$.58491 + .032612\ D^2H$	if $D^2H \leq 707$	.9720	$1.5963\ D^2H^{1.1379}$
	$.58491 + .032612\ (707) + .020363\ (D^2H - 707)$	if $D^2H > 707$		
Bole	$.22066 + .021581\ D^2H$	if $D^2H \leq 707$	.9793	$.4494\ D^2H^{1.2230}$
	$.22066 + .021581\ (707) + .017058\ (D^2H - 707)$	if $D^2H > 707$		
Wood	$.10506 + .019636\ D^2H$	if $D^2H \leq 707$	.9812	$.4188\ D^2H^{1.1993}$
	$.10506 + .019636\ (707) + .014877\ (D^2H - 707)$	if $D^2H > 707$		
Bark*	$.11560 + .001945\ D^2H$	if $D^2H \leq 707$	.9763	$.0227\ D^2H^{1.1724}$
	$.11560 + .001945\ (707) + .002181\ (D^2H - 707)$	if $D^2H > 707$		
Branches	$.02902 + .0060430\ D^2H$	if $D^2H \leq 707$	.7784	$.2847\ D^2H^{1.2110}$
	$.02902 + .0060430\ (707) + .0027842\ (D^2H - 707)$	if $D^2H > 707$		
Fol. + twigs*	$.33523 + .004988\ D^2H$	if $D^2H \leq 707$	.6101	$.6909\ D^2H^{.8701}$
	$.33523 + .004988\ (707) + .0005208\ (D^2H - 707)$	if $D^2H > 707$		
white birch (n = 275)				
Total	$.86088 + .03223\ D^2H$	if $D^2H \leq 644$	.9606	$1.5623\ D^2H^{1.4805}$
	$.86088 + .03223\ (644) + .028457\ (D^2H - 644)$	if $D^2H > 644$		
Bole	$.40056 + .022499\ D^2H$	if $D^2H \leq 644$	.9796	$.8386\ D^2H^{1.3466}$
	$.40056 + .022499\ (644) + .021292\ (D^2H - 644)$	if $D^2H > 644$		
Wood	$.33209 + .018701\ D^2H$	if $D^2H \leq 644$	.9825	$.6124\ D^2H^{1.5233}$
	$.33209 + .018701\ (644) + .018145\ (D^2H - 644)$	if $D^2H > 644$		
Bark*	$.06847 + .003798\ D^2H$	if $D^2H \leq 644$	.9642	$.0178\ D^2H^{1.5877}$
	$.06847 + .003798\ (644) + .003147\ (D^2H - 644)$	if $D^2H > 644$		
Branches	$.22646 + .0043362\ D^2H$	if $D^2H \leq 644$	.6222	$.2515\ D^2H^{1.7166}$
	$.22646 + .0043362\ (644) + .0066231\ (D^2H - 644)$	if $D^2H > 644$		
Fol. + twigs*	$.23386 + .0053948\ D^2H$	if $D^2H \leq 644$	.6854	$.3019\ D^2H^{1.2150}$
	$.23386 + .0053948\ (644) + .0011419\ (D^2H - 644)$	if $D^2H > 644$		

*Coefficient adjusted to make predictions additive.

LITERATURE CITED

Alemdag, I.S. 1980. Manual of data collection and processing for the development of forest biomass relationships. Environment Canada, Canadian Forestry Service, Petawawa National Forestry Instute. Information Report PI-X-4. 38 p.

Anonymous. 1977. The forest management inventory of Newfoundland. Dept. Forestry and Agriculture, Information Report F1-5. 32 p.

Cunia, T. 1964. Weighted least squares method and construction of volume tables. For. Sci. 10:180-191.

Cunia, T. 1979. On tree biomass tables and regressions: Some statistical comments. In: Forest Resource Inventories. Vol. II (W.E. Frayer, ed.) Dept. Forestry and Wood Sciences. Colorado State University, Fort Collins. pp. 629-642.

Dixon, W.J. (ed.) 1981. BMDP Statistical Software 1981. University of California Press, Berkeley, 726 p.

Draper, N.R. and H. Smith. 1981. Applied Regression Analysis, 2nd Ed. John Wiley and Sons Inc., New York.

Ker, M.F. 1974. Metric tree volume tables for Newfoundland. Environment Canada, Canadian Forestry Service, Newfoundland Forest Research Centre. Information Report N-X-122. 24 p.

Ker, M.F. 1980. Tree biomass equations for seven species in southwestern New Brunswick. Environment Canada, Canadian Forestry Service, Maritimes Forest Research Centre. Information Report M-X-114. 18 p.

Lavigne, M.B. and R.S. van Nostrand. 1981. Biomas equations for six tree species in central Newfoundland. Environment Canada, Canadian Forestry Service, Newfoundland Forest Research Centre. Information Report N-X-199. 17 p. + App.

Page, G., A.J. Robinson, R.S. van Nostrand and T.G. Honer. 1971. Volume tables for the major tree species of Newfoundland. Environment Canada, Canadian Forestry Service, Newfoundland Forest Research Centre. Information Report N-X-67. 15 p. + App.

Schreuder, H.T. and W.T. Swank. 1973. Statistical considerations in sampling biomass and surface area over time for a *Pinus strobus* L. forest. *In:* IUFRO Biomass Studies. College of Life Sciences and Agriculture, Univ. Maine at Orono, pp. 131-142.

Schumacher, F.X. and R.A. Chapman. 1954. Sampling methods in forestry and range management. Duke Univ., School of Forestry. Bull 7, Revised. 222 p.

APPENDIX I

Plots of residuals of tree mass prediction equations.

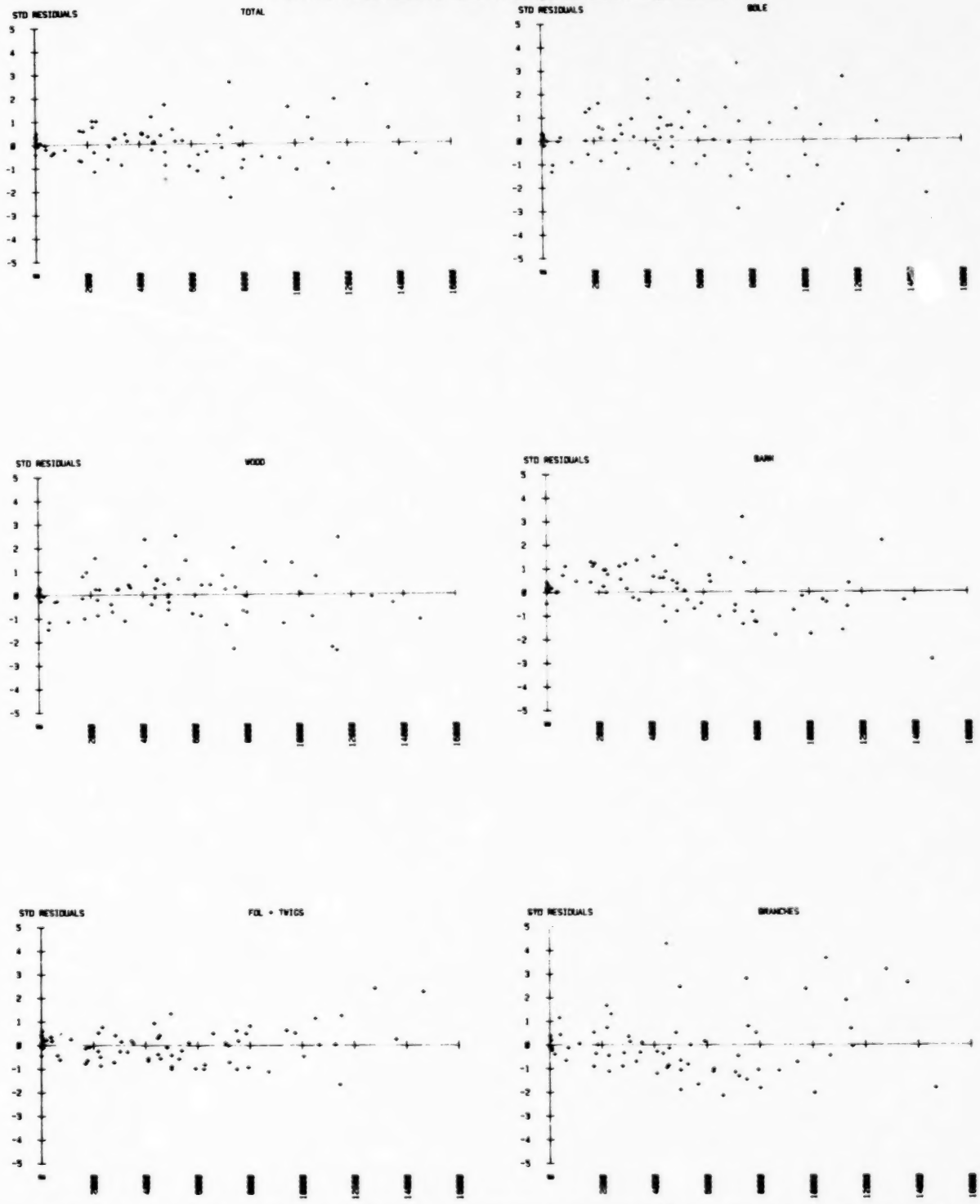

FIGURE 2. Plots of residuals about prediction equations versus D^2H for balsam fir from central Newfoundland.

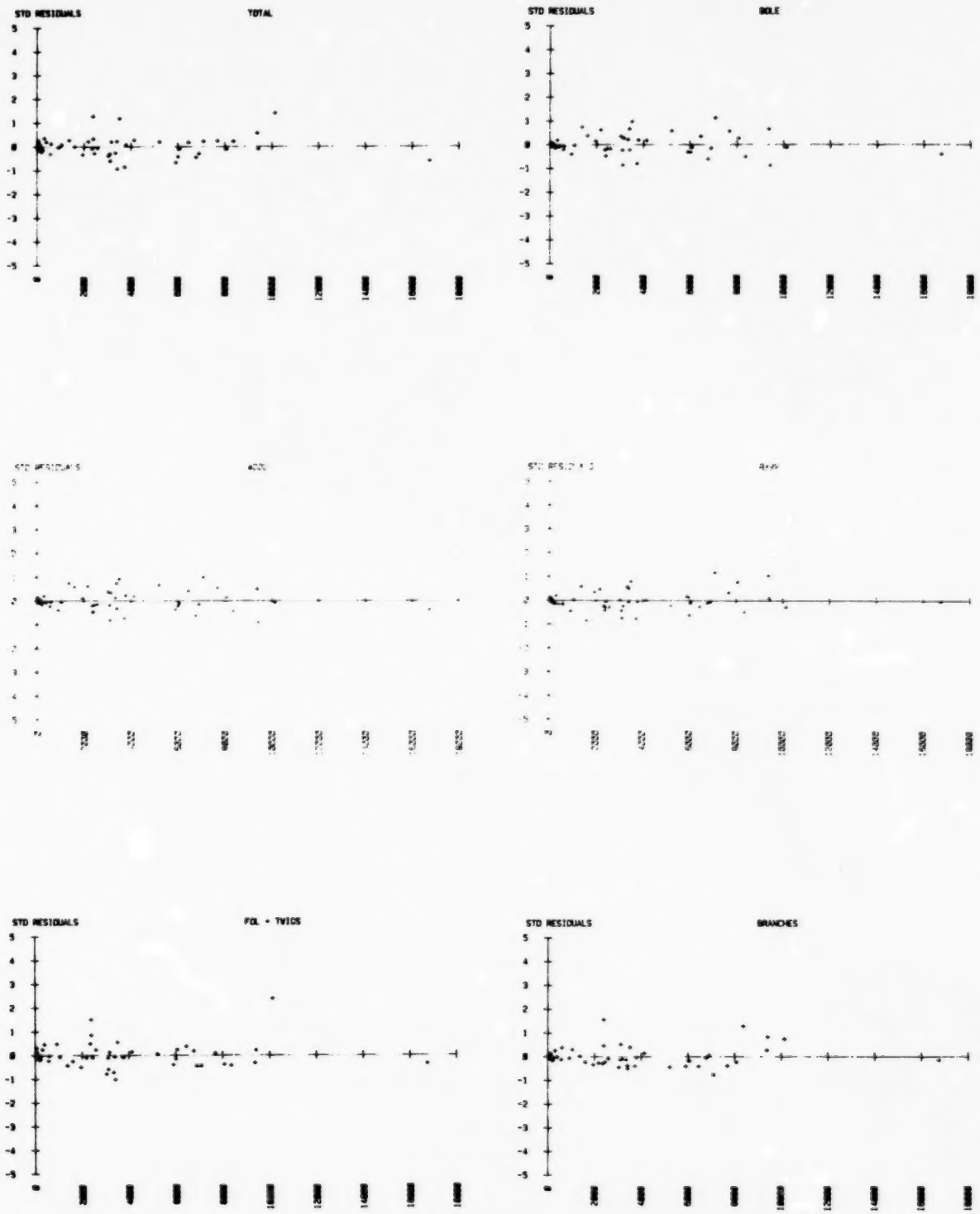

FIGURE 3. Plots of residuals about prediction equations versus D^2H for white spruce from central Newfoundland.

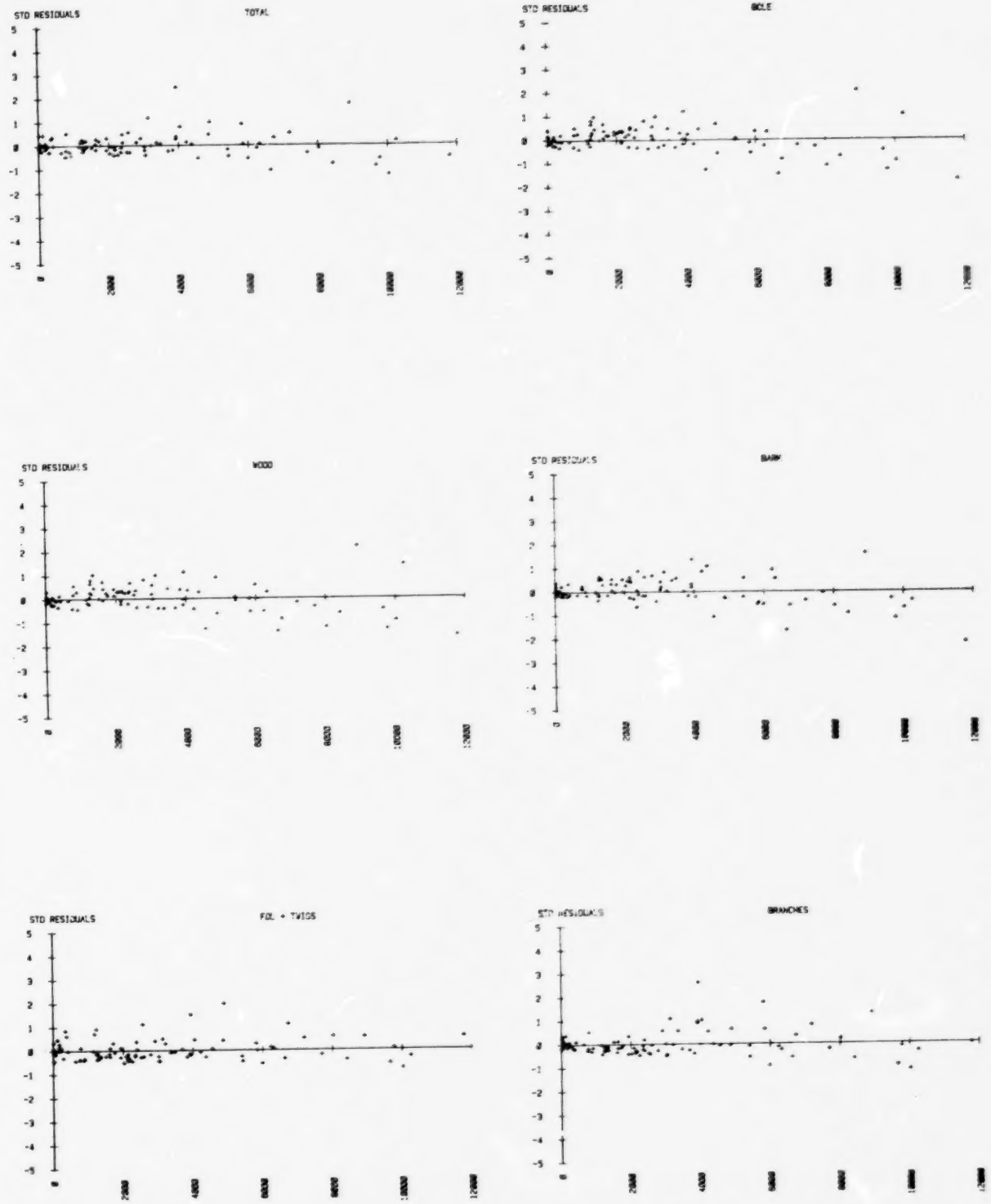

FIGURE 4. Plots of residuals about prediction equations versus D^2H for black spruce from central Newfoundland.

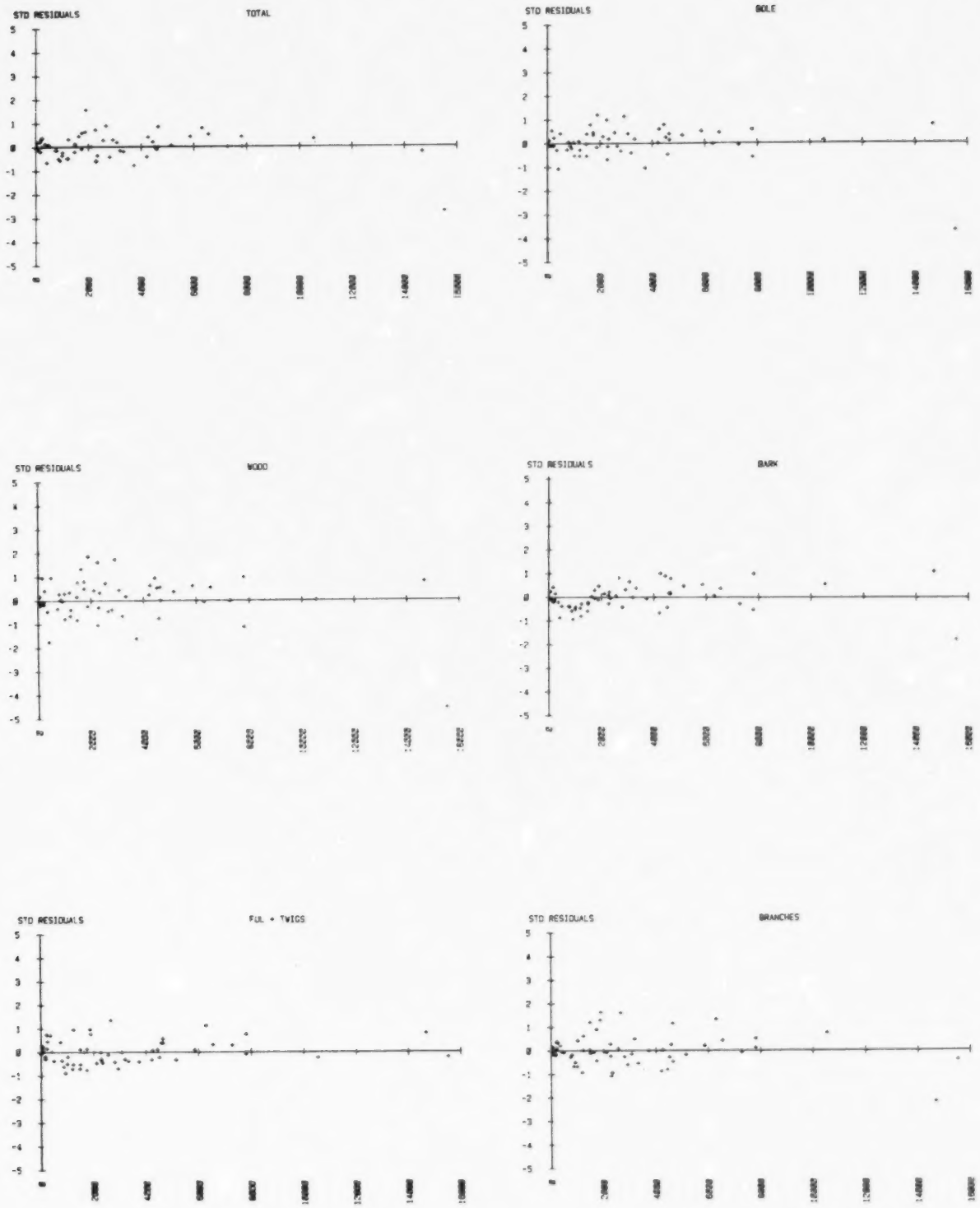

FIGURE 5. Plots of residuals about prediction equations versus D^2H for larch from central Newfoundland.

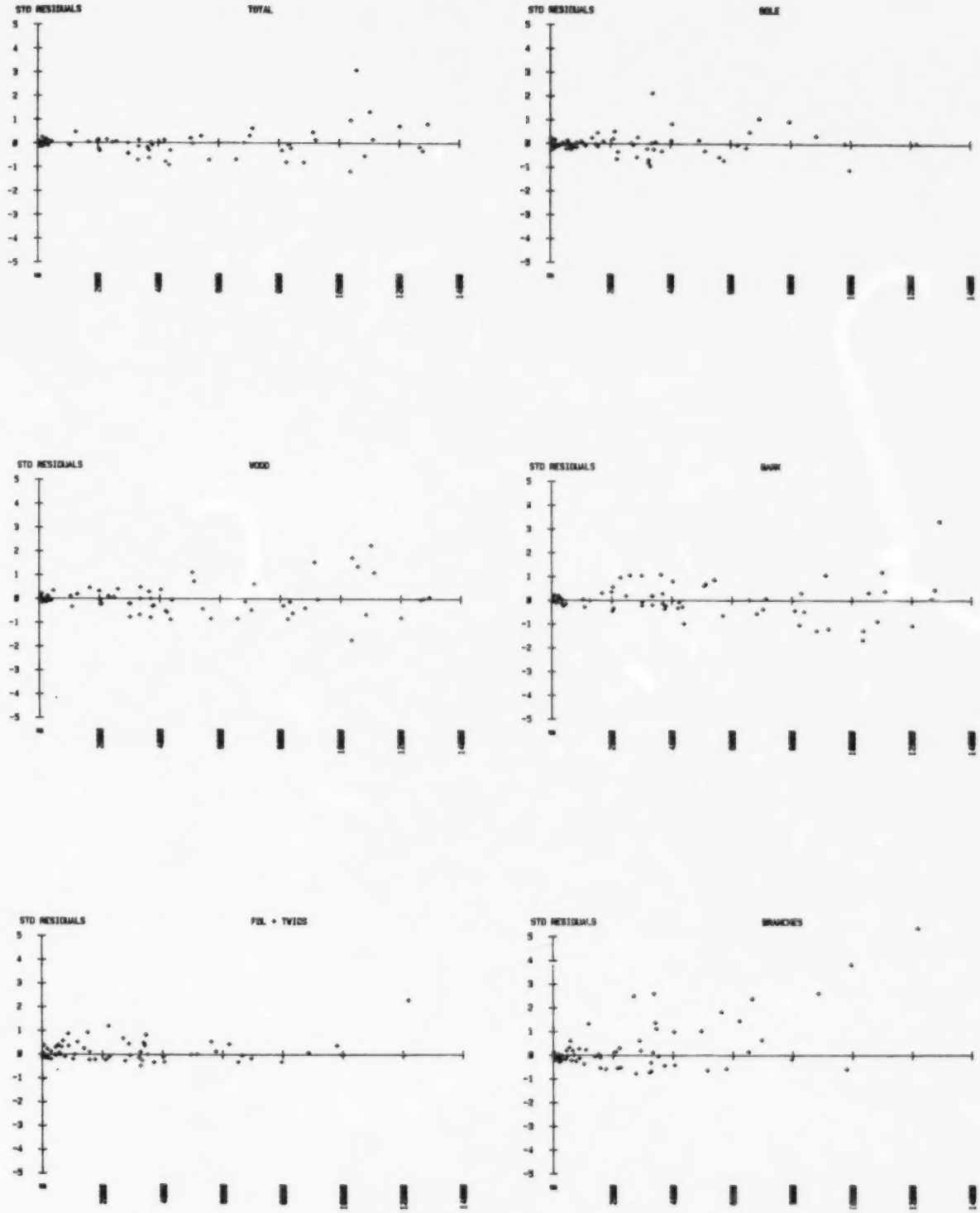

FIGURE 6. Plots of residuals about prediction equations versus D^2H for white birch from central Newfoundland.

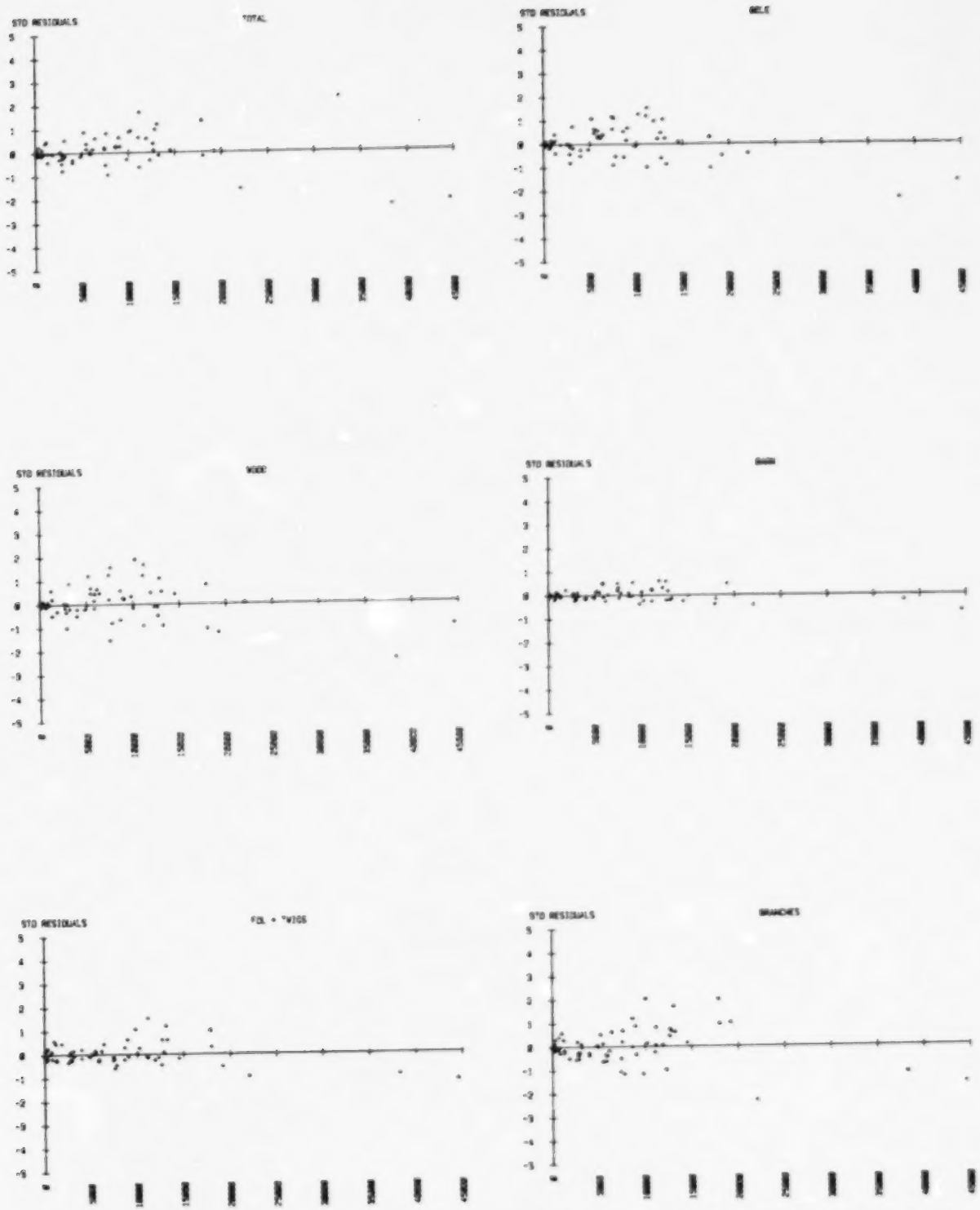

FIGURE 7. Plots of residuals about prediction equations versus D^2H for trembling aspen from central Newfoundland.

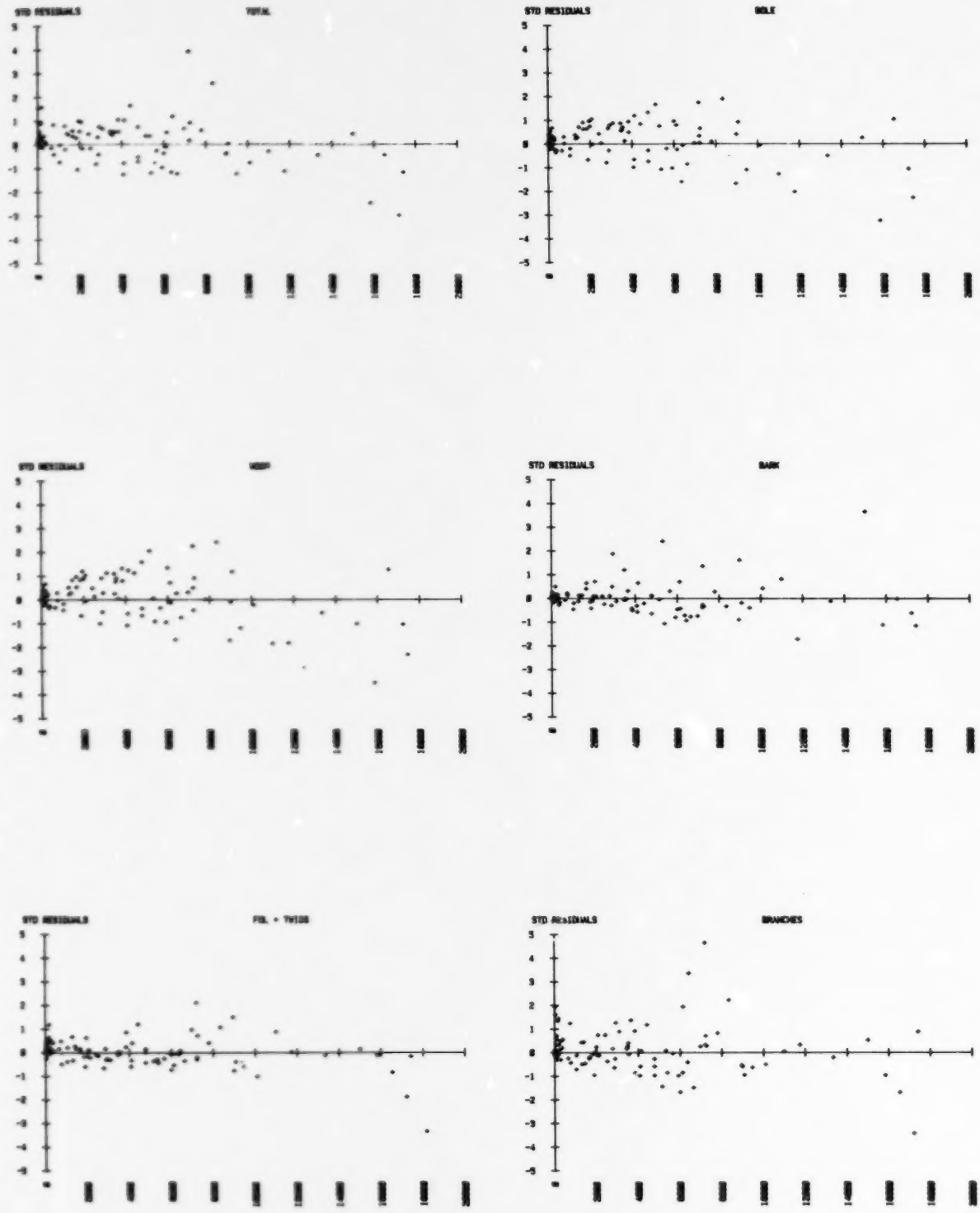

FIGURE 8. Plots of residuals about prediction equations versus D^2H for balsam fir from western Newfoundland.

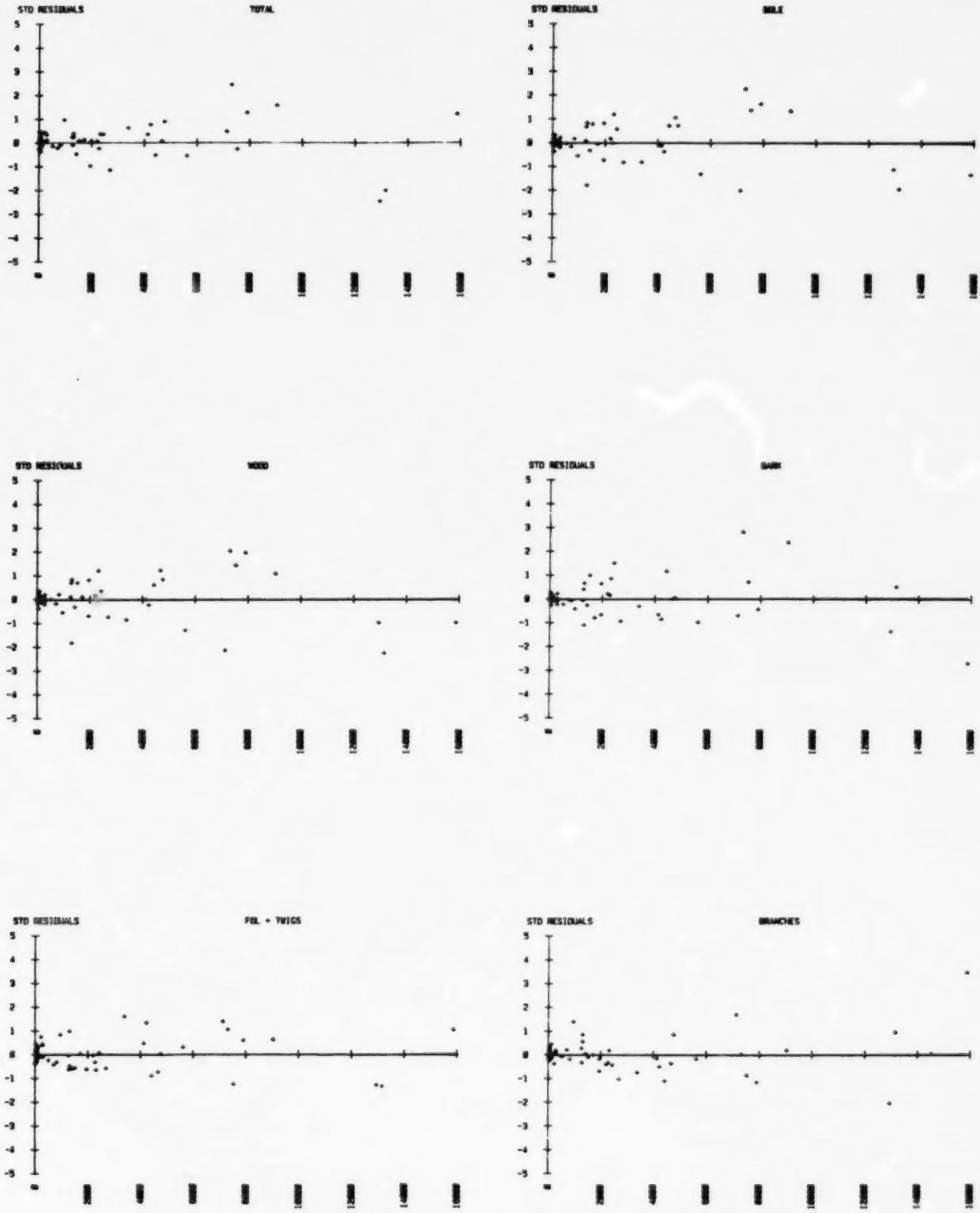

FIGURE 9. Plots of residuals about prediction equations versus D^2H for white spruce from western Newfoundland.

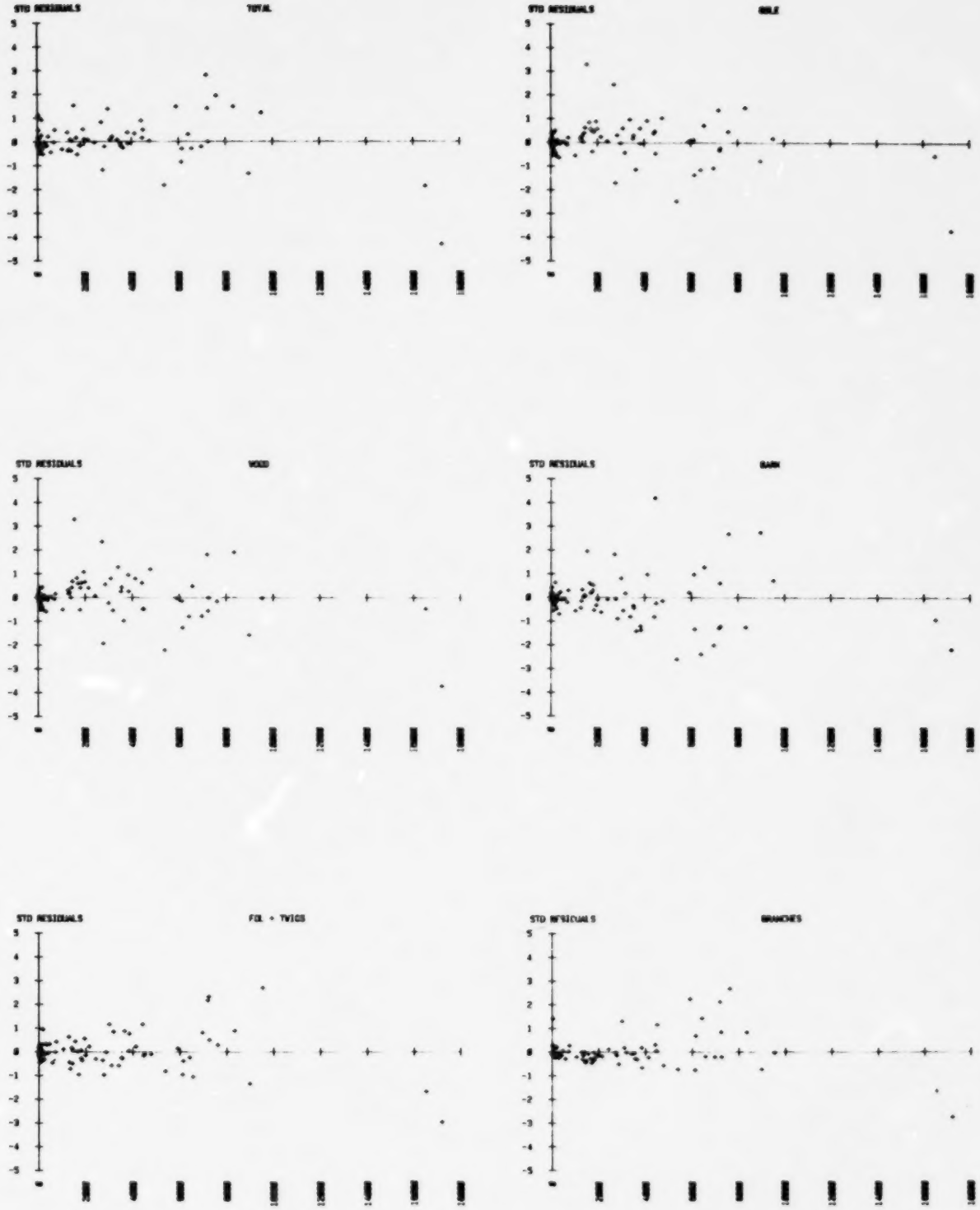

FIGURE 10. Plots of residuals about prediction equations versus D^2H for black spruce from western Newfoundland.

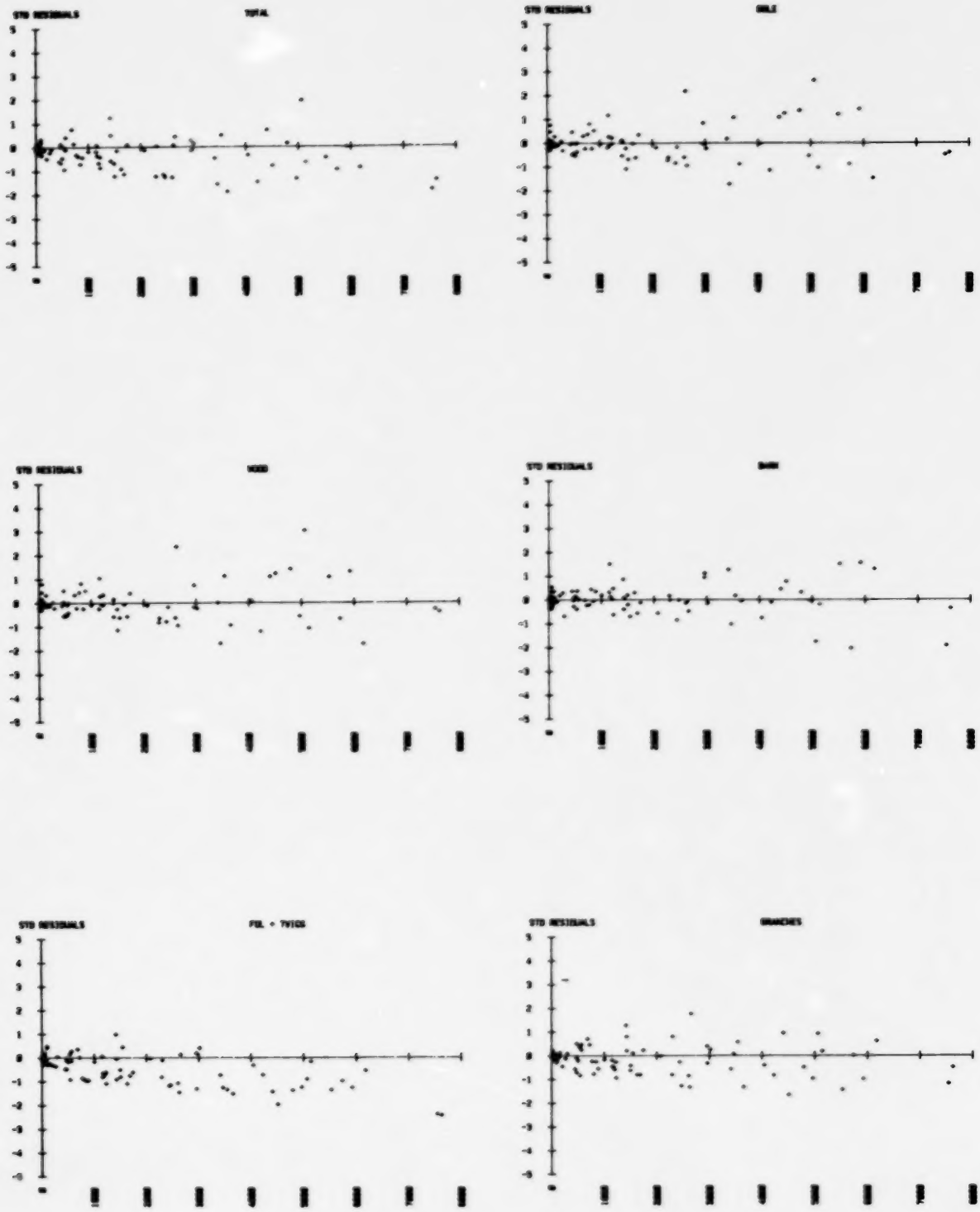

FIGURE 11. Plots of residuals about prediction equations versus D^2H for larch from western Newfoundland.

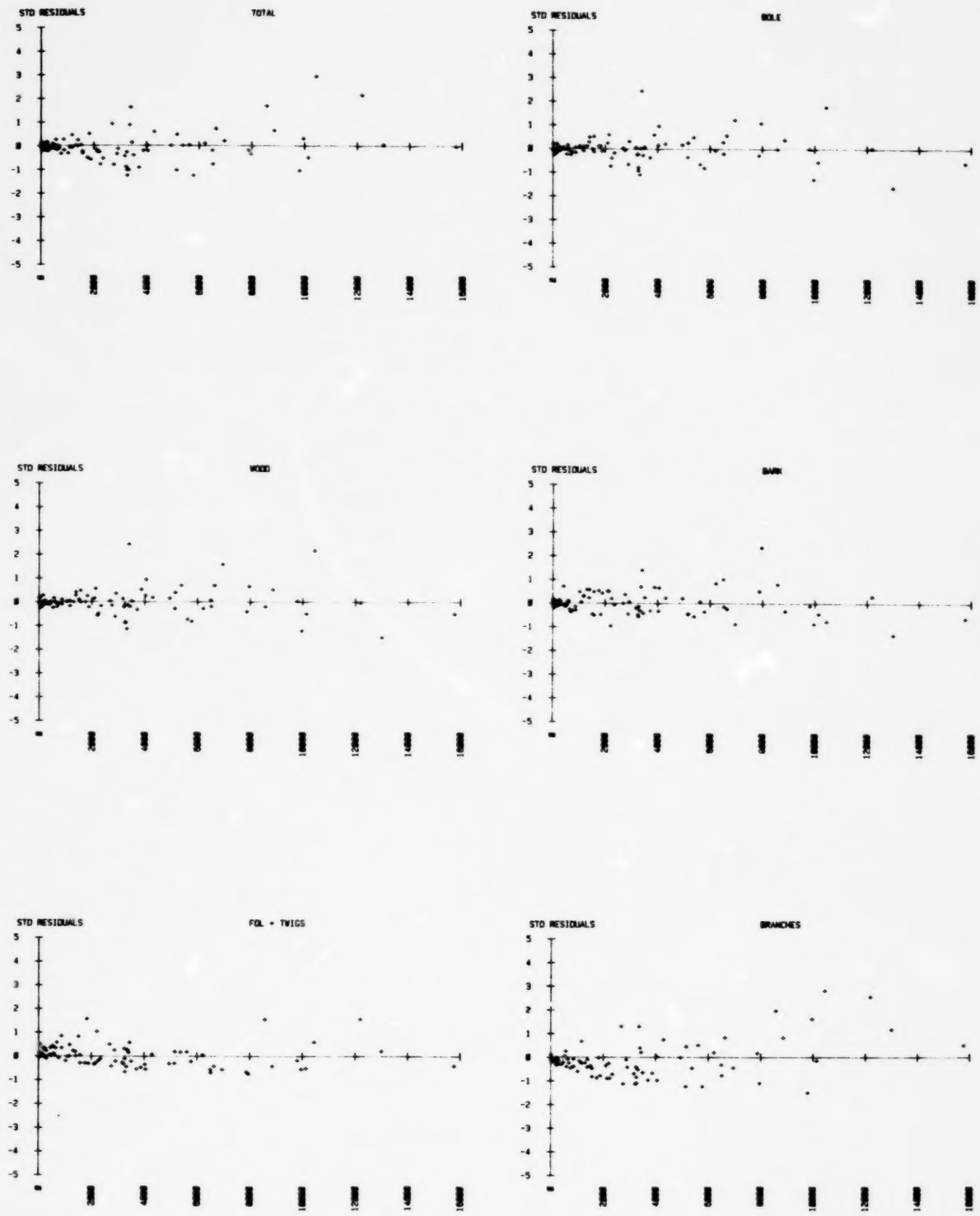

FIGURE 12. Plots of residuals about prediction equations versus D^2H for white birch from western Newfoundland.

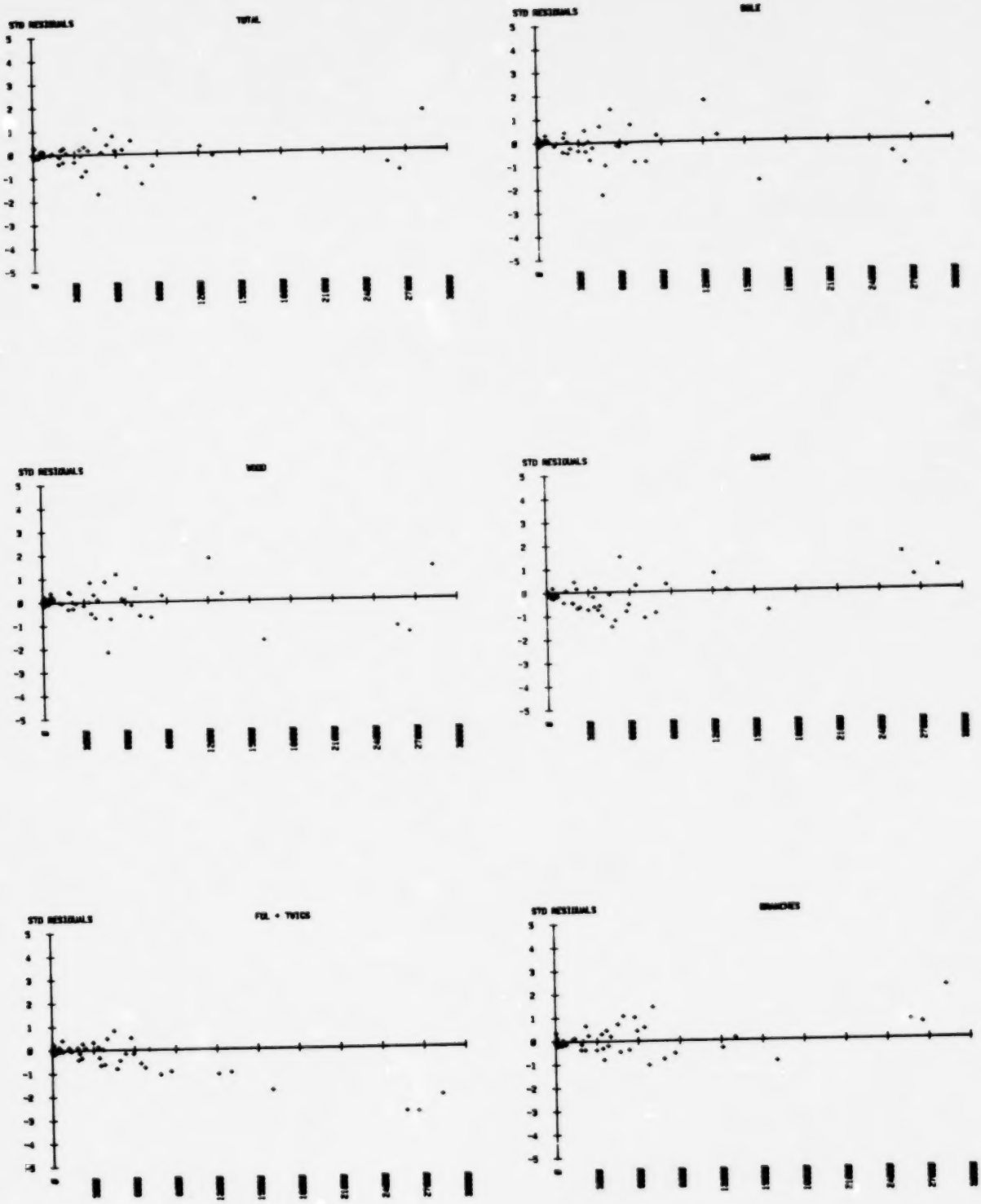

FIGURE 13. Plots of residuals about prediction equations versus D^2H for yellow birch from western Newfoundland.

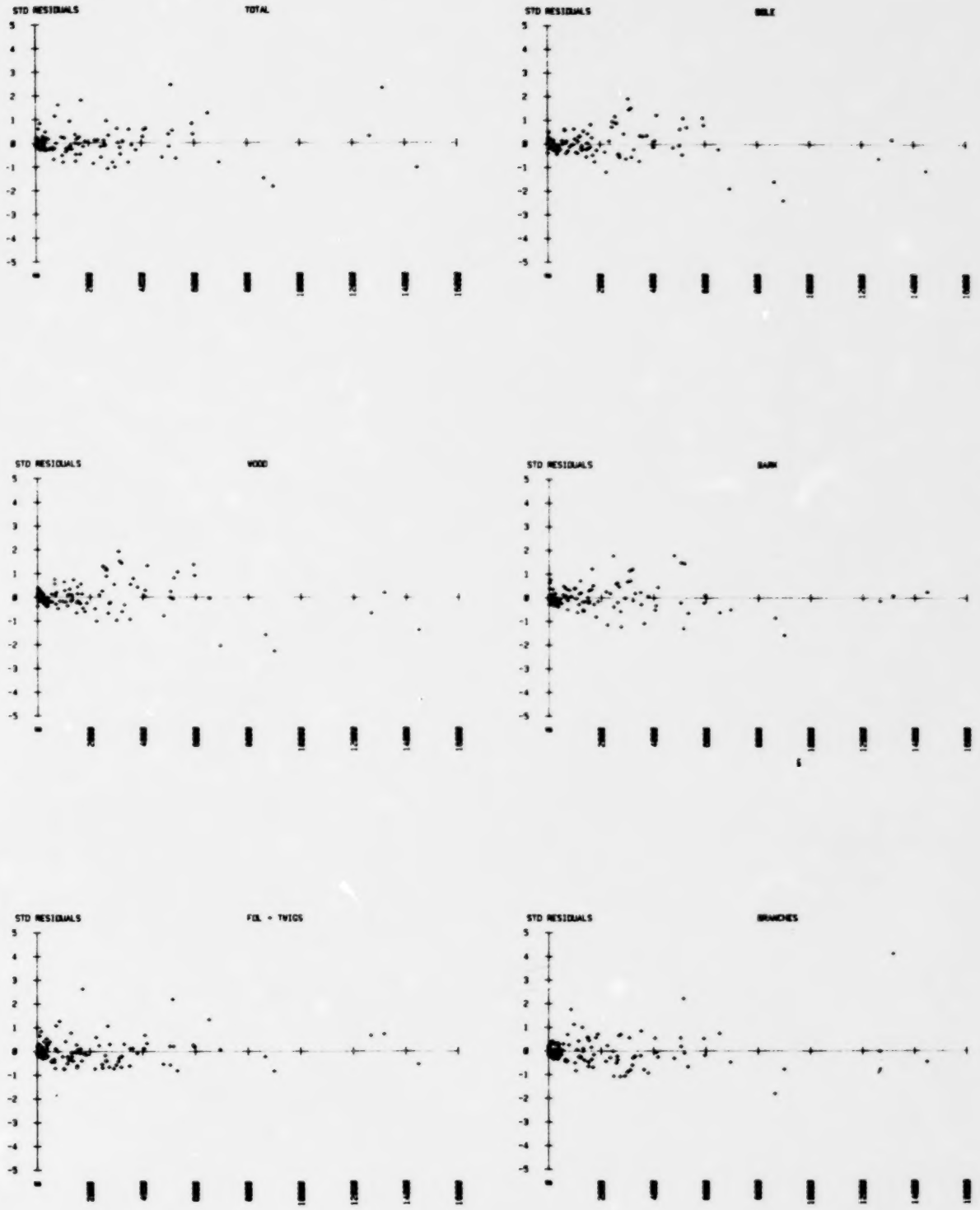

FIGURE 14. Plots of residuals about prediction equations versus D^2H for balsam fir from eastern Newfoundland.

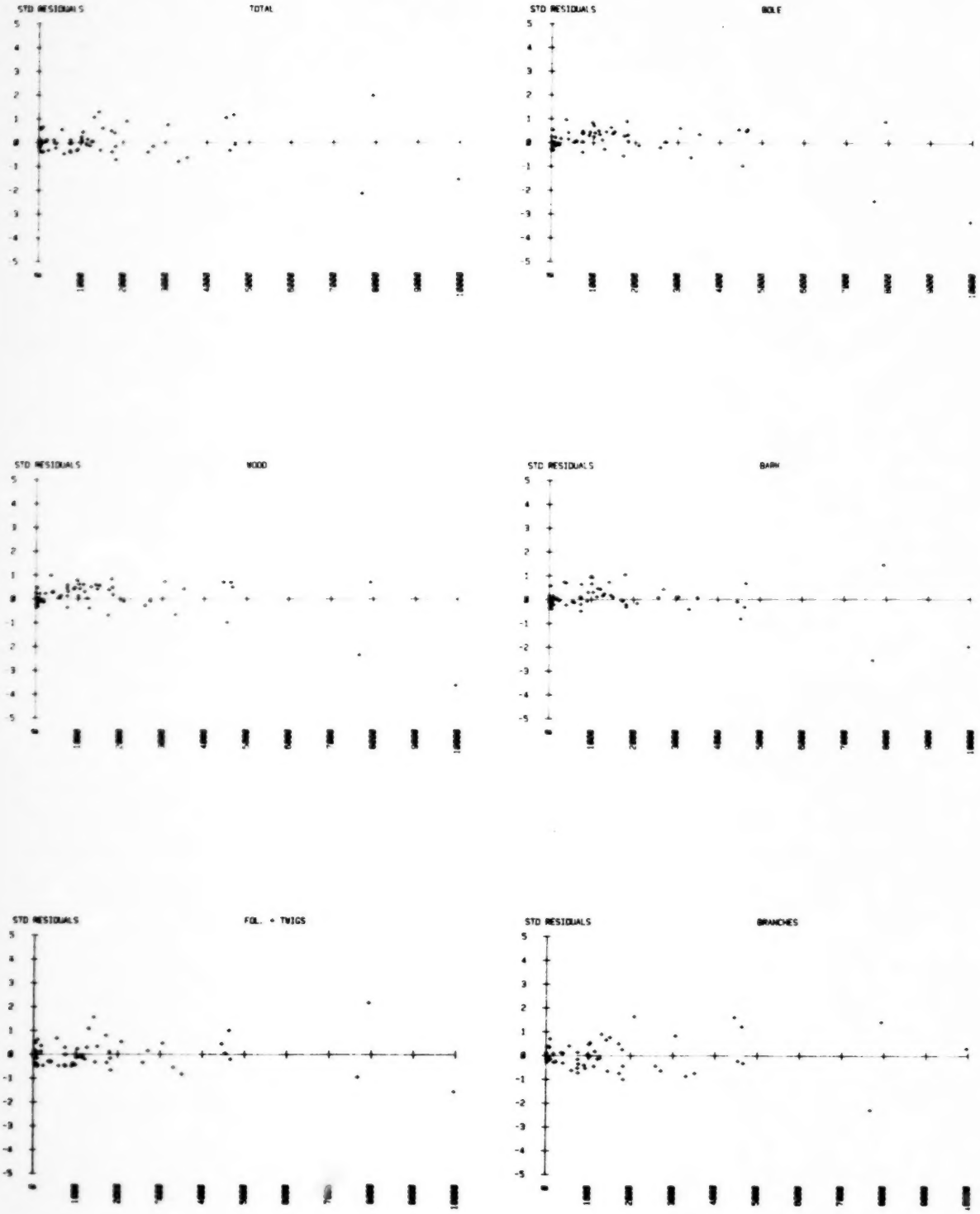

FIGURE 15. Plots of residuals about prediction equations versus D^2H for white spruce from eastern Newfoundland.

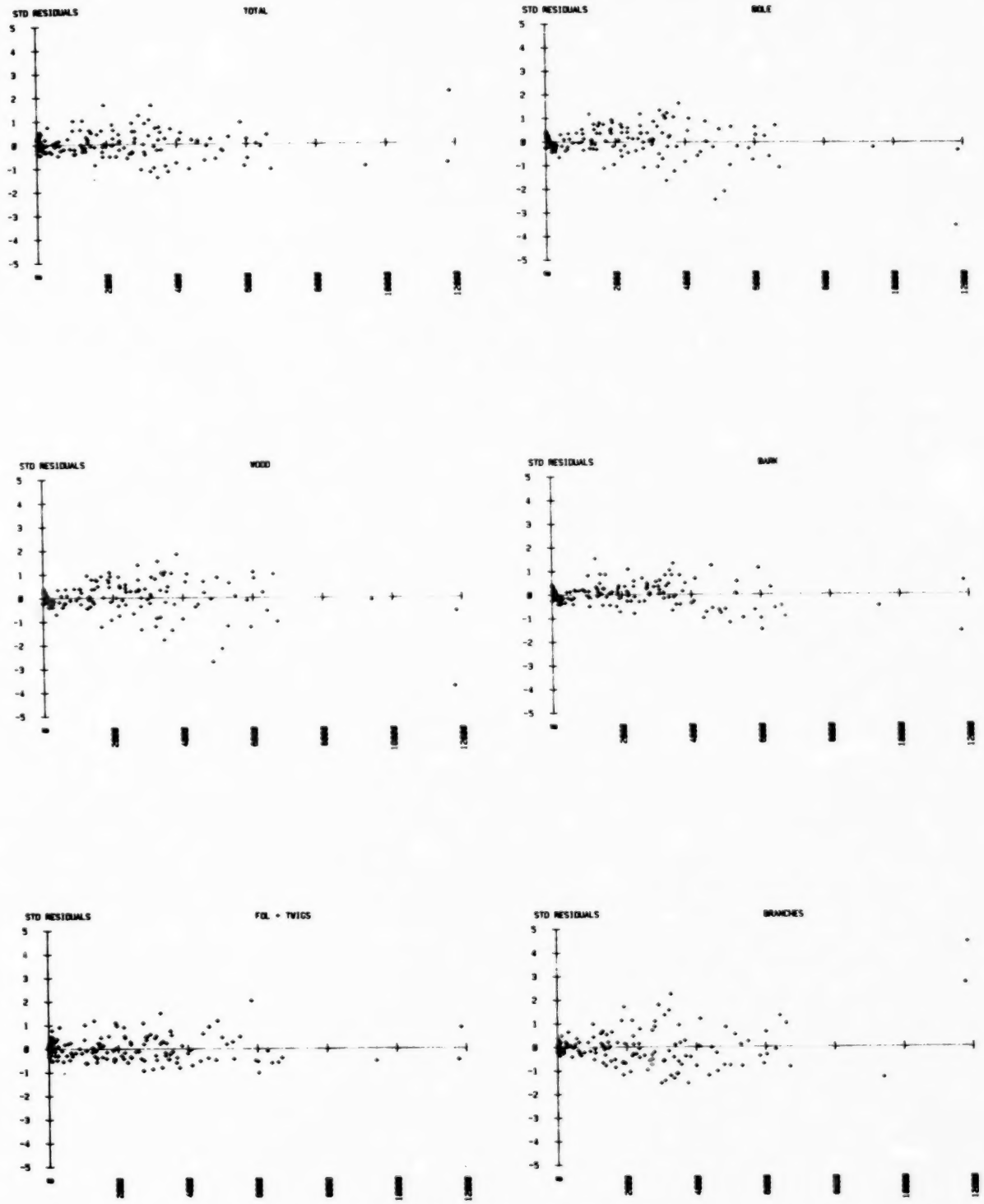

FIGURE 16. Plots of residuals about prediction equations versus D^2H for black spruce from eastern Newfoundland.

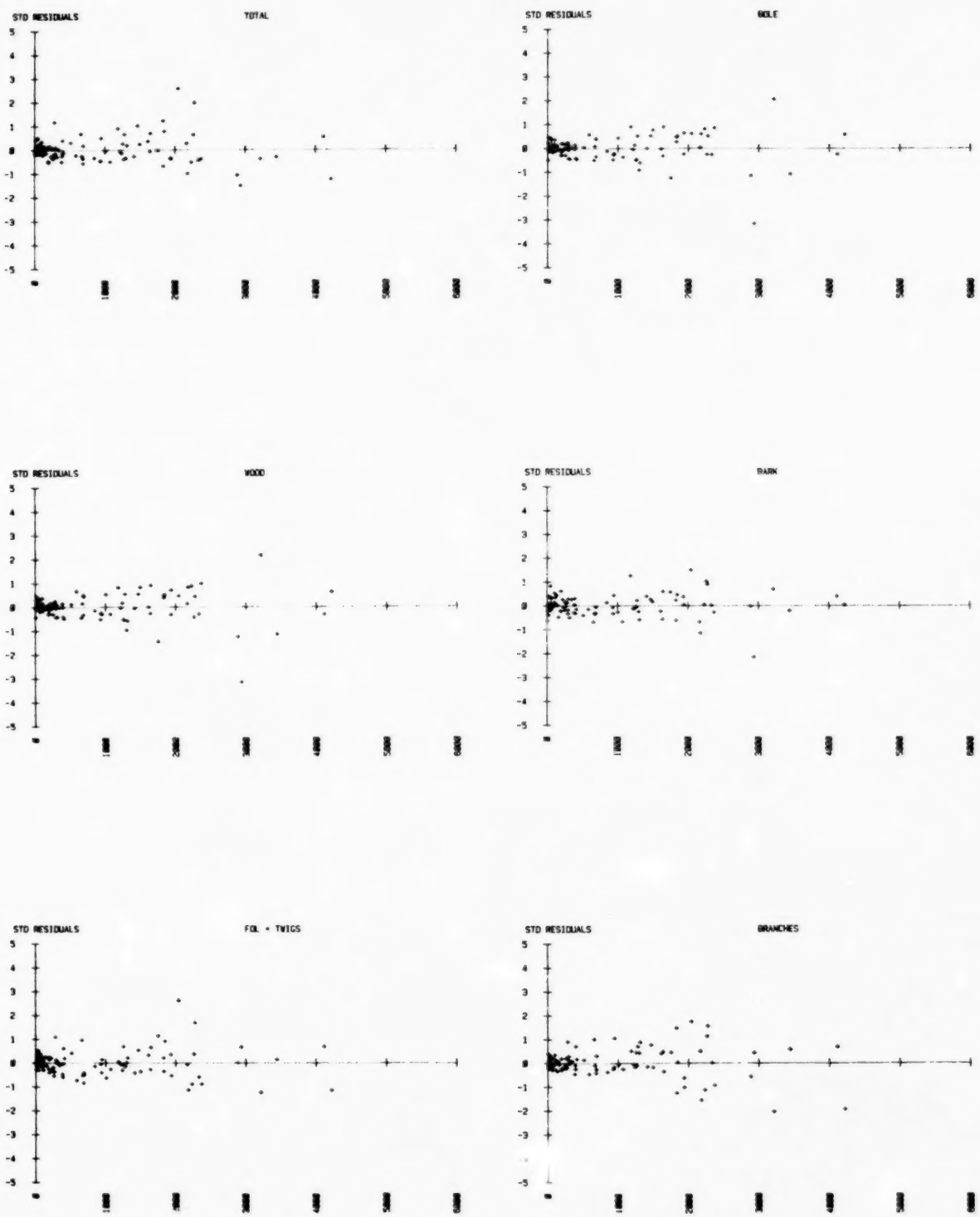

FIGURE 17. Plots of residuals about prediction equations versus D^2H for larch from eastern Newfoundland.

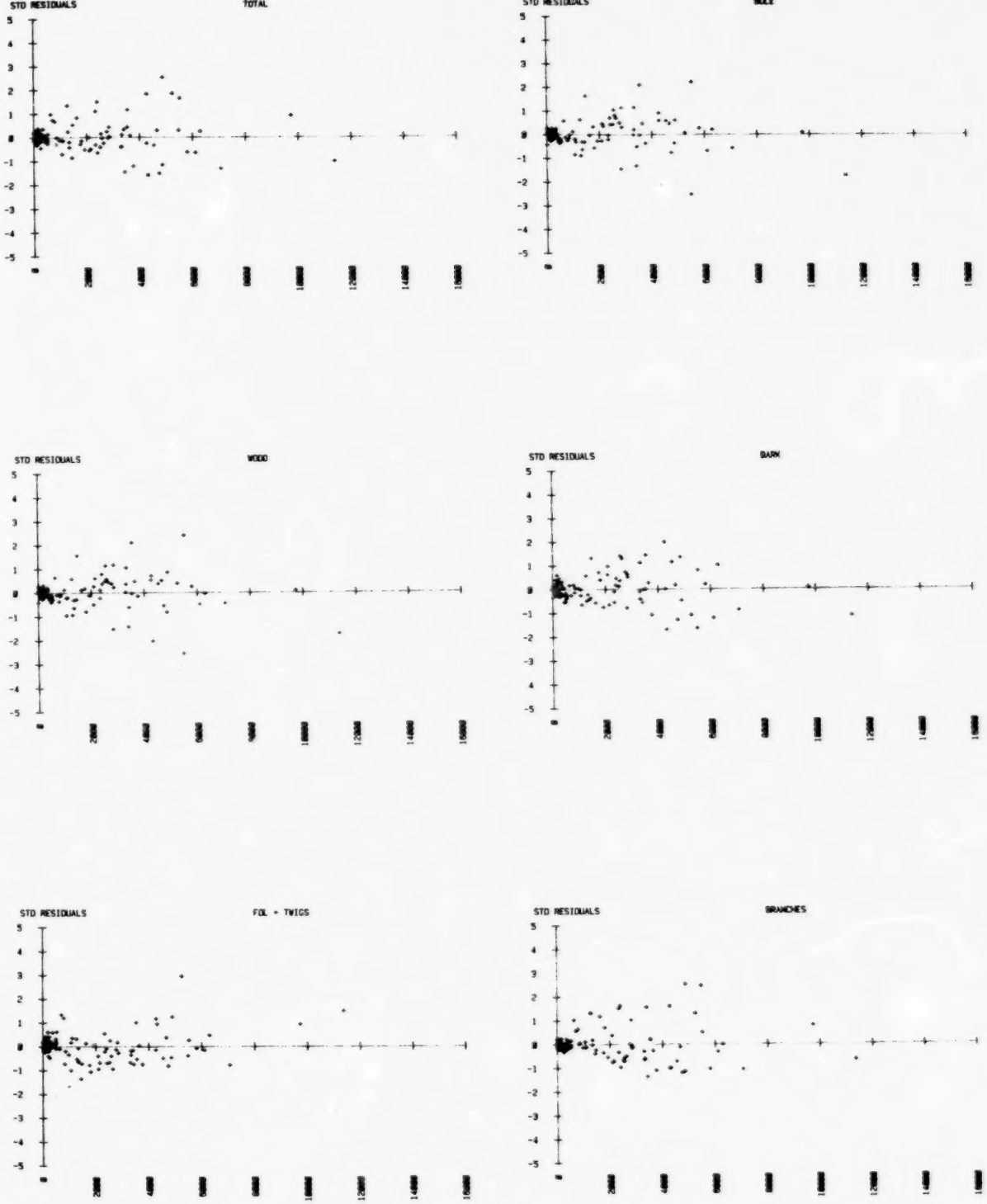

FIGURE 18. Plots of residuals about prediction equations versus D^2H for white birch from eastern Newfoundland.

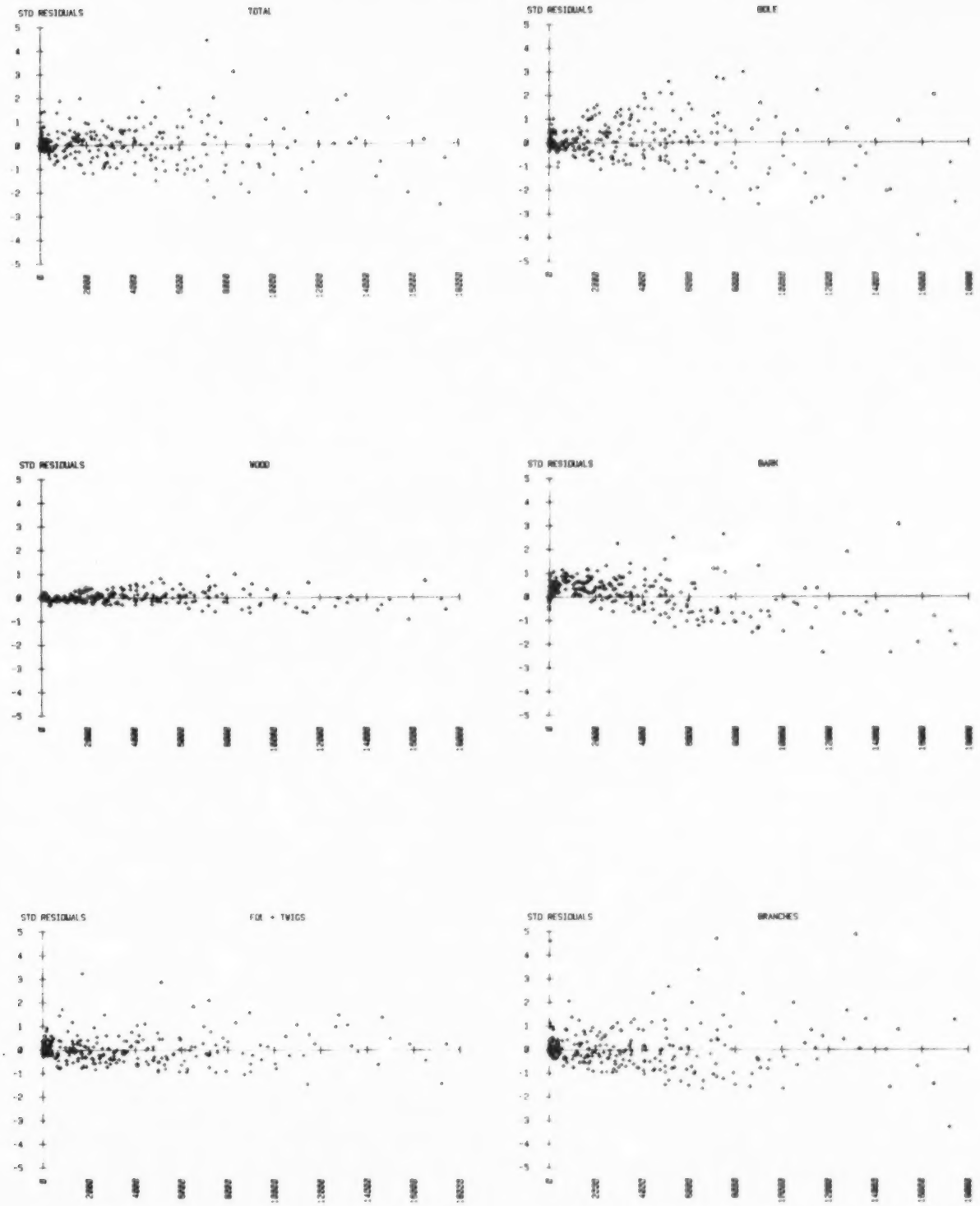

FIGURE 19. Plots of residuals about prediction equations versus D^2H for balsam fir from the island of Newfoundland.

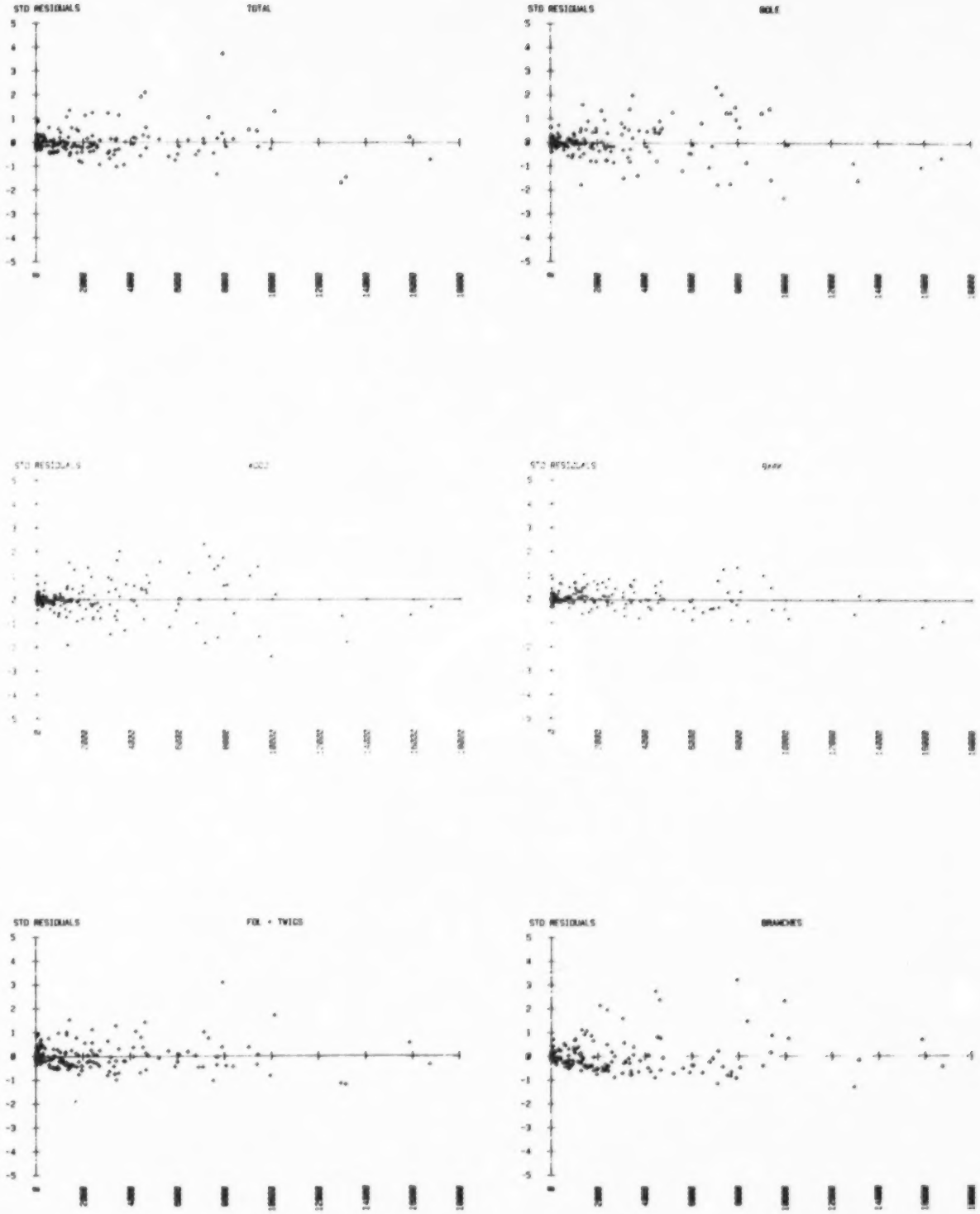

FIGURE 20. Plots of residuals about prediction equations versus D^2H for white spruce from the island of Newfoundland.

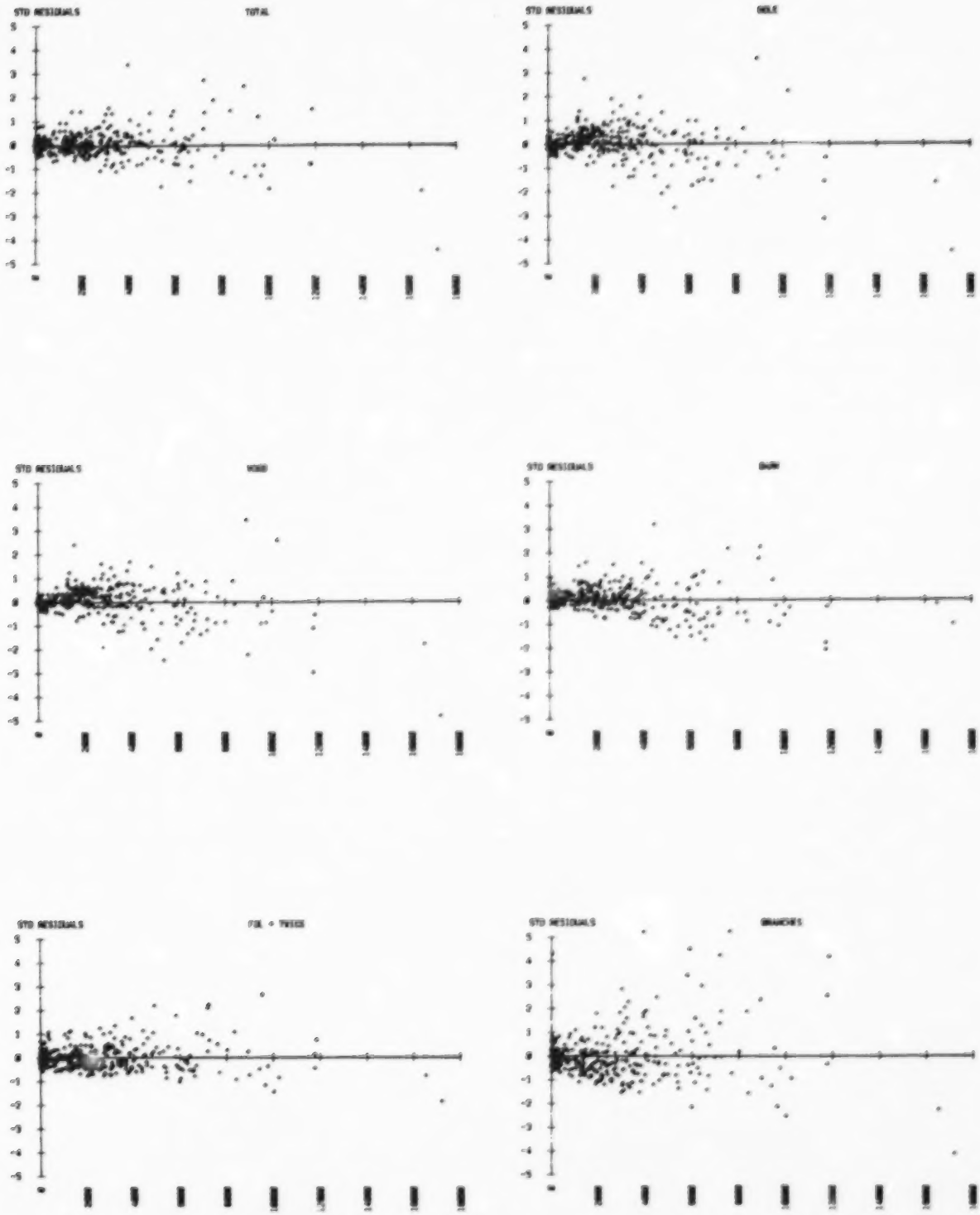

FIGURE 21. Plots of residuals about prediction equations versus D^2H for black spruce from the island of Newfoundland.

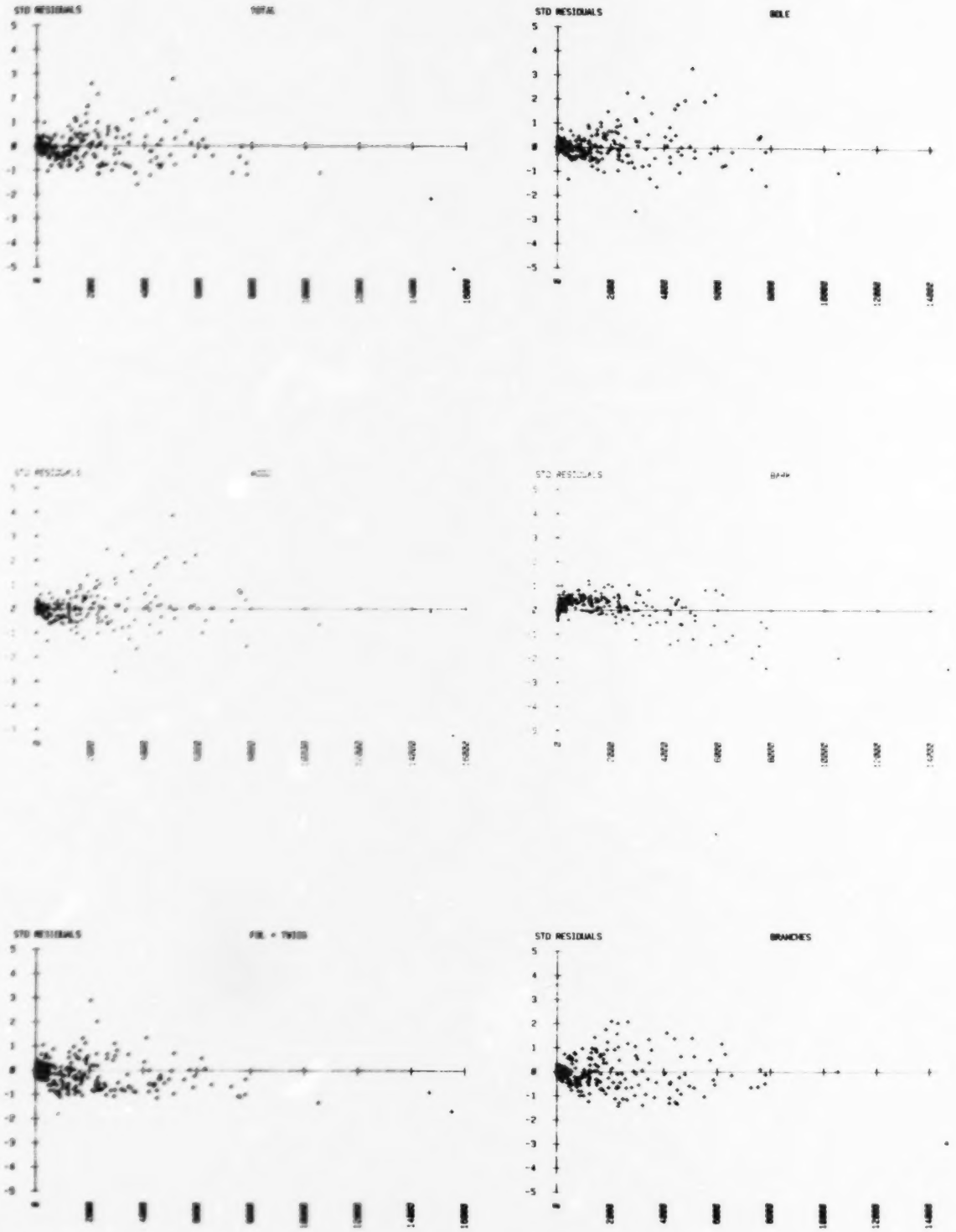

FIGURE 22. Plots of residuals about prediction equations versus D^2H for larch from the island of Newfoundland.

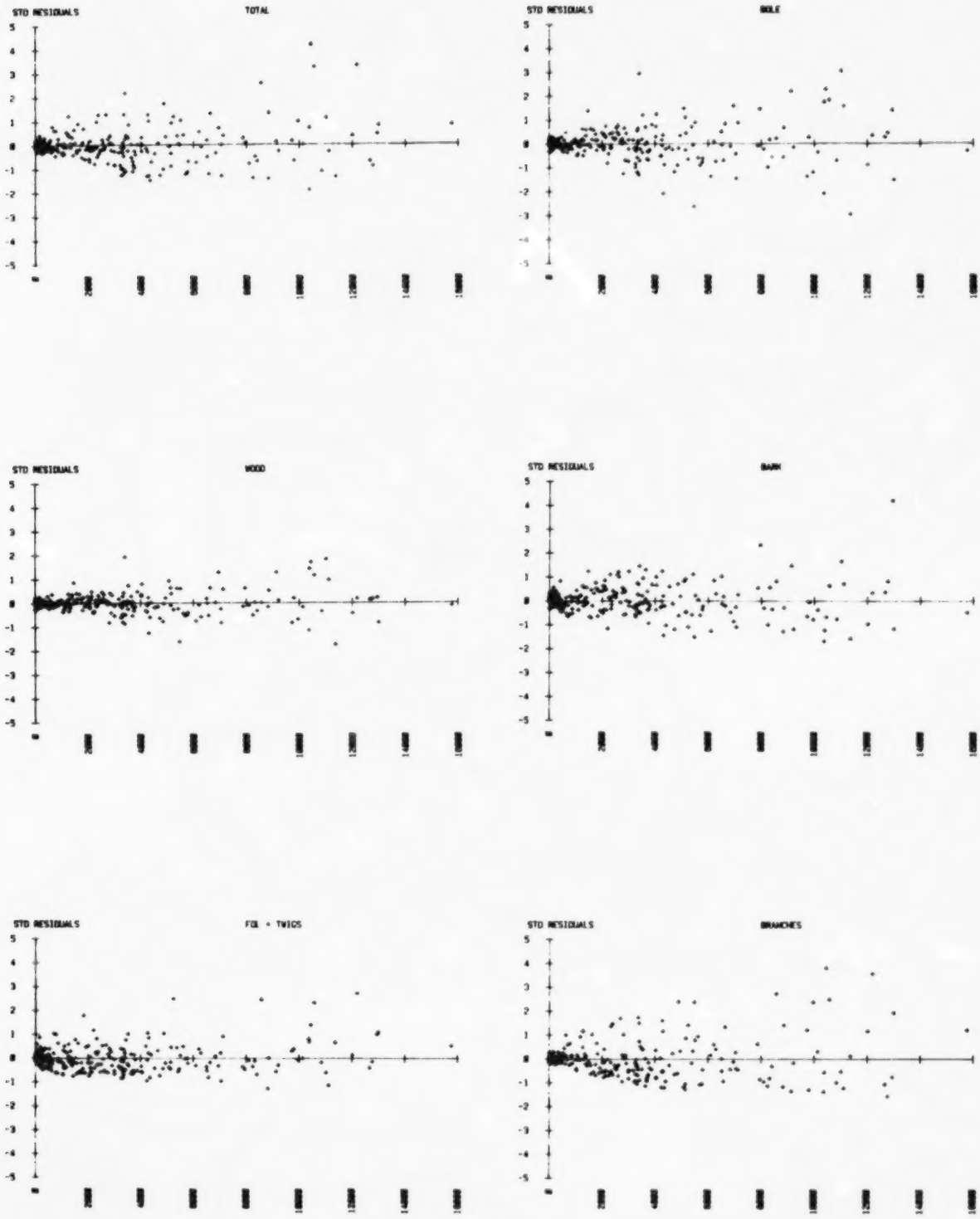

FIGURE 23. Plots of residuals about prediction equations versus D^2H for white birch from the island of Newfoundland.

APPENDIX II

Field and Laboratory Procedures for Obtaining Data Used in Developing Tree Biomass Equations

DEFINITIONS AND STANDARDS OF MEASUREMENT

1. **Ground level** (GL) – top of root collar. On sloping ground this is the level on the up-hill side of the tree.

2. **Diameters** – measured by diameter tape to nearest 1.0 mm. Where a knot is encountered, the diameter directly below the knot should be recorded, with no length adjustment recorded.

3. **Heights** and section lengths – measured with metallic or steel tape to nearest 1.0 cm.

4. **Tree Weights,** green – weighed with a suitable scale to nearest 0.1 kg (100 gm) – taken as soon as practicable after felling tree.

5. **Sample weights,** green and oven-dry (discs, bark, twigs, leaves) – weighed with precision balance to nearest 0.1 gm. Green weights to be taken same day as felling, or at the latest, within 24 hours.

FIELD PROCEDURES

Stand Selection

Sampling was confined to the productive forest sites. Stands were selected using a stratified sampling system, making use of the Newfoundland Forest Inventory map sheets and field plots where practical. These stands were within a reasonable distance of a road, unless extreme conditions dictated otherwise, e.g. stands of balsam fir relatively undamaged by budworm were somewhat rare.

Table 7 gives the minimum number of stands and trees sampled for each species. This table was a guideline for the contractor.

Table 7. Sampling distribution.

Age class	Site 1 class	No. of stands	No. of trees in each diameter class per stand						Total
			I	II	III	IV	V	VI	
0-20	U.	2	1	2					6
0-20	L.	2	1	1					4
21-40	U.	1	2	1	1	1			5
21-40	L.	1	2	1	1				4
41-60	U.	2			1	1	1	1	8
41-60	L.	2		1	1	1	1		8
61-80	U.	1			1	1	1	2	5
61-80	L.	1			1	1	1	1	4
81+	U.	1			1	1	1	2	5
81+	L.	1			1	1	1	1	4
Total		14	8	10	10	9	8	8	53

[1]U. site classes high and good of the Provincial Forest Management Inventory. L. site classes poor and medium of the Provincial Forest Management Inventory.

Tree Selection

1. Randomly selected a point within the stand.

2. Conducted a prism or relascope sweep and counted trees by species to obtain working group and basal area.

3. Facing magnetic north and moving clockwise with the relascope, selected the first trees of the desired diameter and species included in the count (see Table 27). Not more than one tree of any one species and diameter class was selected from a stand, except as noted. If all required diameters were not included in the count, additional points were selected, within the same stand, until the diameter quota was filled. In cases where trees in the largest diameter class were not present in the stand, an additional tree was selected from the next lower diameter class. In cases where the age of the selected tree differed by more than 20 years from the stand age, another tree was selcted.

White spruce was taken whenver encountered at a point sample. These trees were taken in addition to those of the other species.

Balsam fir, because of the situation with respect to insect attack, was selected on the basis of tree condition. No severely defoliated tree was taken. Balsam fir stands and trees were chosen by deliberate selection, keeping in mind the desirability of a wide distribution of ages, sites, and locations.

Larch stand were selected from plot locations established during the larch survey conducted across the Island during 1976-78.

Deviations from the above sampling procedures and schedule were allowed when it became obvious that certain combinations of sepcies, age, and site could not be located. In such cases, trees of equivalent diameter classes were selected from stands of the more common sites and ages for that species.

Sample Tree Procedure

A. **For trees > 9.0 cm Dbh**

1. Breast height (1.3 m above GL) was marked on the stem. Maximum crown diameter was estimated to nearest 0.1 m.

2. Cleaned area of brush and debris where tree was to fall. Tree was cut at 0.3 m above GL.

3. Measured and recorded height from GL to base of crown.

4. All branches were cut off, leaving tip on the stem.

   a. **Softwoods**

   (i) Subdivied branches into three groups; (a) dead branches; (b) live branches with basal diameters > 3 cm (measured ob 3 cm from base of branch); and (c) live branches with basal diameters < 3 cm.

   (ii) Weighed and recorded green weights of each group.

   (iii) Randomly selected two branches from each of the three groups, or a minimum of 4 branches when all groups were not represented. Placed in plastic bags separately for each group. These branch samples were used to estimate dry crown component weights.

   b. **Hardwoods**

   (i) Live branches were cut into sections 2 m long and sorted into three groups based on the mid-diameter ob of each section; (a) those < 3 cm dob including all foliage; (b) those between 3 and 9 cm dob, and (c) those > 9 cm dob. All dead branches formed a separate fourth group.

(ii) Recorded green weights for each of the four groups.

(iii) Randomly selected four branches with leaves from the < 3 cm dob group.

(iv) Three discs were cut at random from each of the two remaining live-branch groups, and from the dead branches.

(v) Labelled and placed samples in plastic bags separately for each group. These samples were used to estimate dry crown weights.

5. On main stem (softwoods and hardwoods) measured and recorded:

   (a) total length from GL to top of tree;

   (b) length from GL to point on stem where dob was 9.0 cm (merchantable height);

   (c) Dob at breast height.

6. Main stem was cut at each 2 m interval measured from GL.

7. Stump was cut off as close to GL as was practicable and determined age at 0.3 m.

8. Weighed each section and recorded weights separately – stump, first section above stump, etc.

9. Discs were cut 3 to 4 cm thick at each 2m interval. Disc was taken from the lower end of each section beginning with first section above stump.

10. Labeled and placed in plastic bags. These samples were used to estimate dry stem component weights (wood and bark).

B. **For Trees < 9.0 cm Dbh and >5.0 cm Dbh**

1. Marked BH and tree was cut as close to ground as was practicable.

2. Separated branches from stem.

3. Measured and recorded Dbh and total height.

4. Recorded green weights of stem and branches separately.

5. A disc 3 to 4 cm thick was cut from BH and from the middle of the stem.

6. Randomly selected 4 complete branches and placed separately in plastic bags.

C. **For Trees<5.0 cm Dbh to 2.0 cm Dbh**

1. As for B.1, 2, 3, 4 and 6.

2. A disc 3 to 4 cm thick was cut from BH.

3. For small trees 1 to 2 cm Dbh, cut up the whole tree and placed in plastic bag for processing in the laboratory.

General Stand and Site Descriptions

For each stand from which sample trees were taken the following were determined:

1. Location – latitude and longitude

2. Approximate stand age

3. Basal area of stand using prism or relascope

4. Species composition

LABORATORY PROCEDURES

Trees

A. **Discs**

1. Obtained green weight of each disc (bark on). Removed bark and weighed disc again. Green bark weight was the difference between the two weighings.

2. Dried wood and bark at 105°C for 24 hours, or until there was no weight change. Removed from oven, placed in dissicator until cool, and obtained oven-dry weights separately for wood and bark of each disc.

B. **Branches, Twigs and Leaves**

1. For each branch sample, separated leaf or needle-bearing twigs from rest of branch.
2. Obtained green weights separately for main branch, and twigs plus leaves.
3. Oven-dried as for discs.
4. Obtained oven-dry weights separately for main branch, and twigs plus leaves.

C. **Whole Small Trees (1-2 cm Dbh)**

1. Separated branches from stem.
2. Separated leaf-bearing twigs from branches.
3. Obtained green weights separately for stem, branches, and twigs plus leaves.
4. Obtained oven-dry weights as above, for stem, branches and twigs plus leaves.

DATA PROCESSING

All data obtained from the field and laboratory procedures outlined above was key-punched into the computer system at the Newfoundland Forest Research Centre by the contractor for later processing by the Centre.

Species and Working Groups

bs – 11

wS – 13

bF – 21

Larch – 31

wB – 71

tA – 61

Site:

High – H

Good – G

U = 1

Medium – M

Poor – P

L = 2

Age Class (Total age–;

0-20 – 1

21-40 – 2

41-60 – 3

61-80 – 4

81+ – 5

Diameter Classes

0-5 cm – 1

6-10 cm – 2

11-15 cm – 3

16-20 cm – 4

21-25 cm – 5

26-30 cm – 6

Latitude and Longitude

Recorded in degrees, minutes and seconds.